The Journal of Bone and Joint Surgery

ROBERT JONES CENTENARY VOLUME

ROBERT JONES 1857–1933

Robert Jones was born one hundred years ago. His seventy-six years of life were dedicated to the care of the injured and crippled, and he earned the title " Founder of Modern Orthopaedic Surgery " which to-day is inscribed on a plaque over the entrance to the orthopaedic wards of the Royal Liverpool Southern Hospital which he served for thirty years from 1889 to 1918.

The centenary will be commemorated with deep respect, gratitude and warm affection by all the associations and groups of surgeons who were inspired in their work by him. The British Orthopaedic Association which he founded, having honoured him first as President and then as President-Emeritus throughout his life, is meeting this month in his own hospital—the Robert Jones and Agnes Hunt Orthopaedic Hospital, Oswestry, Shropshire. The International Society of Orthopaedics and Traumatology, of which he was founder-President and later permanent-President, will make special recognition at its forthcoming meeting in Spain. The Royal College of Surgeons of Edinburgh, of which Robert Jones was so distinguished a Fellow, will honour his memory, as will the Royal College of Surgeons of England, which shares with the University of Liverpool the responsibilities of the Robert Jones Lectureship and the Research Fellowship. In the Liverpool Cathedral where his ashes are laid there will be a service on June 28, the day of his birth. The Robert Jones Club will meet for the first time in its history out of London; it will meet in Liverpool. The Osler Club of London is honouring his memory by a special lecture.

This issue of the *Journal of Bone and Joint Surgery*, published jointly in Great Britain and the United States, is dedicated to a great surgeon who allied and fused the affections and endeavours of the surgeons of these two nations. On the front cover is a reproduction of the gold medal he awarded to postgraduate students who distinguished themselves in the School of Orthopaedics and the examinations for the degree of Master of Orthopaedic Surgery which he established in the University of Liverpool. On the open pages of a book is inscribed *Fiat Lux*; and below is written *Haec Otia Studia Fovent*. But the memory of Robert Jones is not alone that of making light out of darkness by studious endeavour and academic achievement, with relief of suffering and crippling by surgical measures; much more is his memory related to the encouraging and stimulating influence of a warm-hearted man who inspired young surgeons, so that inevitably they became his disciples. Thus we are privileged to publish personal tributes from Viscount Malvern, Lord Cohen, Sir Thomas Fairbank, Dr Joel Goldthwait, Professor Edward Gallie, Dr Philip Wilson, Dr Leo Mayer, Sir Max Page, Professor Bryan McFarland, Professor George Perkins and many others.

Would that we could also have published messages from H.M. King Manuel of Portugal, Vittorio Putti of Bologna, Murk Jansen of Leiden, Jacques Calvé of Berck-Plage, Robert Lovett of Harvard, Nathaniel Allison and Robert Osgood of Boston, Clarence Starr of Toronto, Sir Harold Stiles of Edinburgh, Sir Henry Gray of Aberdeen, Brownlow Mitchell of Belfast, Sir William de Courcy Wheeler of Dublin, Sir John Lynn-Thomas of Cardiff, Lord Moynihan of Leeds, Sir Arthur Keith, Professor Wood Jones, Naughton Dunn, Rowley Bristow, Gathorne Girdlestone, Tom McMurray, Ernest Hey Groves, Muirhead Little, Blundell Bankart, Alwyn Smith, R. C. Elmslie and so many others who were his close colleagues and friends. But their duty is done, and they are no longer with us. The one satisfaction that we can gain is that the next generation of orthopaedic surgeons, and even the youngest of them, is eager to pay tribute to his memory.

EDITOR.

From Sir Reginald Watson-Jones

Liverpool, Oswestry, London

The kindly word, the encouraging smile, the twinkling eye with creases all going up in the right direction, and the whole magnetic personality of Robert Jones, seem as vivid to-day as they were thirty years ago when he was at the peak of his endeavour in creating and establishing the principles, science and art of orthopaedic surgery. Perhaps his greatest contribution was to the art of surgery because he taught us all to be so infectious in our happiness that disabled and distressed patients also became happy. I never knew a more joyful man with his quips, pranks, jokes and beaming smile, so that when he went to Baschurch in earlier days, and to Oswestry in later days, the children almost fell out of bed and certainly out of their spinal frames in order to laugh with him. So too at Roehampton in the years of the first world war his enthusiastic spirit of happiness made wounded soldiers believe that life could still be good.

Fig. 1

Hugh Owen Thomas, as always with peaked cap and smoking a cigarette, talking to his nephew, Robert Jones, who at that time was so young that he even had his hands in his pockets.

Robert Jones was born in 1857 at Rhyl, a small town on the North Wales coast; and he died in 1933 at a little village in the Welsh county of Montgomeryshire. All his apprenticeship was served with his uncle Hugh Owen Thomas (Fig. 1), the first to be medically qualified of many generations of unqualified bone-setters who had practised in the hills of Wales and the lowlands of Anglesey, an island off the coast of Wales. There can be no doubt that Robert Jones was a Welshman. But there was no " Welsh Nationalism " about him. Liverpool was the first centre of his activities; then it was London; then Great Britain; then the United States; and then the whole world. It is not a far cry to see that whether in surgery or in any other activity great men do not remain parochial, or local, or national, but rather international and world-wide in their endeavours. The humble origin of Robert Jones in this small Welsh town led ultimately to a great British-American alliance in the world of surgery, and then to

his establishment of the International Society of Orthopaedics and Traumatology, of which he was the first president, this body of surgeons expressing almost inarticulate admiration by creating for him the unprecedented title of " Permanent-President." Interlocal in the beginning, he was international in the end.

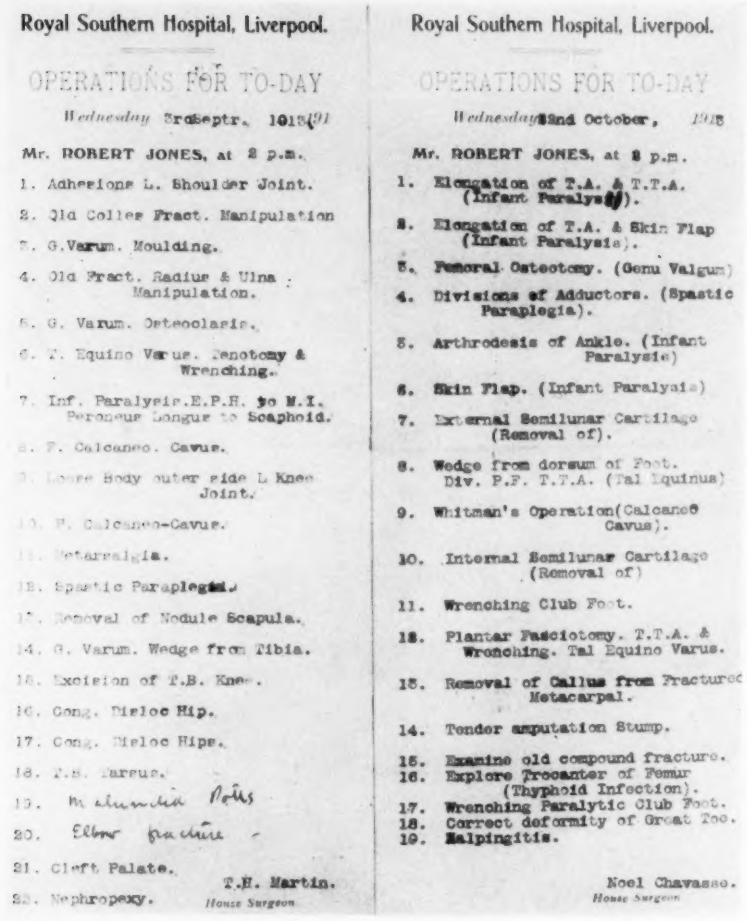
Robert Jones qualified in medicine in 1878, and gained the Fellowship of the Royal College of Surgeons of Edinburgh in 1889. He was soon appointed general surgeon to the Liverpool Stanley Hospital and, while still a young man of thirty years, as general surgeon to the Royal Southern Hospital of Liverpool. This broad surgical experience stood him in good stead in later years when his abilities were applied to that part of general surgery concerned with disorders of the limbs and spine—orthopaedic surgery. He was of course strongly influenced by his uncle Hugh Owen Thomas to whom he was apprenticed at 11 Nelson Street—the house which became a Mecca for surgeons from all over the world. We have said that Hugh Owen

FIG. 2

11 Nelson Street, Liverpool, where Hugh Owen Thomas and Robert Jones pursued their practice. It was destroyed by bombs in the second world war; but the engraved stone has been preserved and is now in the Robert Jones Library in the Liverpool Medical Institute.

Thomas was descended from a long line of Welsh bone-setters; but even his father Evan Thomas, unqualified as he may have been, treated thousands of patients not only from the industrial north of England but from every corner of the globe. Robert Jones could hardly have escaped this traditional influence, or the powerful personality of his uncompromising uncle who battled and fought continuously in favour of safe and conservative treatment as opposed to unsafe, sometimes wild and often dangerous operations.

It was at 11 Nelson Street in Liverpool that Hugh Owen Thomas darted up and down the corridor, into the cubicles on each side, whipping out a wrench concealed beneath his coat-tails to correct a recently malunited Colles's or Pott's fracture before the patient had time to breathe or wonder what it was all about; and here it was that Robert Jones learned not to waste time, and to know the great possibilities of conservative treatment. This famous



Royal Southern Hospital, Liverpool.

OPERATIONS FOR TO-DAY

Wednesday 3rd Septr. 1913

Mr. ROBERT JONES, at 2 p.m.

1. Adhesions L. Shoulder Joint.
2. Old Colles Fract. Manipulation
3. G.Varum. Moulding.
4. Old Fract. Radius & Ulna : Manipulation.
5. G. Varum. Osteoclasis.
6. T. Equino Varus. Tenotomy & Wrenching.
7. Inf. Paralysis.E.P.H. to M.I. Peroneus Longus to Scaphoid.
8. T. Calcaneo. Cavus.
9. Loose Body outer side L Knee Joint.
10. T. Calcaneo-Cavus.
11. Metatarsalgia.
12. Spastic Paraplegia.
13. Removal of Nodule Scapula.
14. G. Varum. Wedge from Tibia.
15. Excision of T.B. Knee.
16. Cong. Disloc Hip.
17. Cong. Disloc Hips.
18. T.B. Tarsus.
19. Malunited Colles
20. Elbow fracture
21. Cleft Palate.
22. Nephropexy.

T.H. Martin.
House Surgeon

Royal Southern Hospital, Liverpool.

OPERATIONS FOR TO-DAY

Wednesday 22nd October, 1913

Mr. ROBERT JONES, at 2 p.m.

1. Elongation of T.A. & T.T.A. (Infant Paralysis).
2. Elongation of T.A. & Skin Flap (Infant Paralysis).
3. Femoral Osteotomy. (Genu Valgum)
4. Divisions of Adductors. (Spastic Paraplegia).
5. Arthrodesis of Ankle. (Infant Paralysis)
6. Skin Flap. (Infant Paralysis)
7. External Semilunar Cartilage (Removal of).
8. Wedge from dorsum of Foot. Div. P.F. T.T.A. (Tal Equinus)
9. Whitman's Operation(Calcaneo Cavus).
10. Internal Semilunar Cartilage (Removal of)
11. Wrenching Club Foot.
12. Plantar Fasciotomy. T.T.A. & Wrenching. Tal Equino Varus.
13. Removal of Callus from Fractured Metacarpal.
14. Tendor amputation Stump.
15. Examine old compound fracture.
16. Explore Trocanter of Femur (Thyphoid Infection).
17. Wrenching Paralytic Club Foot.
18. Correct deformity of Great Toe.
19. Malpingitis.

Noel Chavasse.
House Surgeon

FIG. 3

These are two quite typical operating lists done at the Royal Southern Hospital, Liverpool, by Robert Jones in 1913. It is to be noted that the house-surgeon signing the first list is T. H. Martin, who was the founder of the Leasowe Hospital for Children—a pioneer hospital in this country for the treatment of tuberculous disease of bones and joints.

The second list, dated October 22, 1913, is signed by the house surgeon, Noel Chavasse, son of Bishop Chavasse of Liverpool. Who, at the time that he was assisting Robert Jones as house surgeon, could have predicted that as a medical member of the Armed Forces he would be awarded the Victoria Cross—the most closely guarded and highly treasured of all awards for military service, and so often given posthumously because that is almost the essential character of the award? That being so, who could possibly predict that the Victoria Cross should be awarded **twice**—the V.C. and Bar—to a doctor, for the first and probably the last time in medical history?' That is what happened—and that is the character of some of the house surgeons of Robert Jones.

Such honour to his students and disciples is honour to Robert Jones himself, because he inspired in them loyalty, courage and devotion to duty.

house, having been visited by surgeons from throughout the world who, like the Mayo brothers, intended to stay for a day but found themselves magnetised for a week, was destroyed by a time-action bomb in the second world war. Fortunately the stone above the doorway chiselled " H. O. T. Surgery, 1856 " was recovered from the debris and is preserved in the Hugh Owen Thomas and Robert Jones Library in Liverpool. I, for my sins, having paid some sort of pilgrimage several days after the raid, stole some of the broken tiles from that famous corridor—and I still treasure those fragments.

With this background Robert Jones was versed in the principles of manipulative and conservative treatment, often uncompromisingly antagonistic to the accepted teachings of that day; but to it he allied the newly learned art of aseptic surgery. Thus he became one of the founders of modern orthopaedic surgery. Quite soon his operating lists at the Southern Hospital, varying in length from twenty to thirty operations, starting at 2 o'clock in the afternoon, consisted almost entirely of osteotomies, osteoclases, bone excisions, arthrodeses, elongation of tendons and so on, with a few cases of cleft palate, nephropexy or salpingitis put at the end (Fig. 3). These were left more and more to Theodore Armour, who probably did not mind starting at seven or eight o'clock at night because he never knew one hour from the other, or one day from the next; he often started his ward-rounds at midnight and once sent me to the country to put on a plaster spica only to be met by an irate doctor who said: " but it was to be 4 o'clock *yesterday*, not to-day."

Robert Jones retired from his Liverpool hospital practice before the age of fifty and pursued a vigorous private practice in Liverpool and London, though always maintaining his free Sunday clinics at Nelson Street. But before he did so, his alliance with Agnes Hunt had been created and firmly established. She had first brought children from her derelict country home at Baschurch in Shropshire, where stables had been converted into open-air wards, in what she described to the railway officials as " perambulators " because such transport cost half as much on the railway as stretchers or ambulances. So every Saturday she would arrive in Liverpool with two or three perambulator-loads of crippled children for Robert Jones to operate upon, and take back a similar number of loads to Baschurch. From this very simple, undignified, perhaps illicit, sometimes naughty, but always happy and joyful activity, there developed the great hospital at Gobowen in Shropshire, now the Robert Jones and Agnes Hunt Orthopaedic Hospital, which with its after-care clinics serves ten or more counties, most of the central part of England and Wales, and receives patients not only from all parts of this country but from all over the world. It was the first hospital ever to organise so complete a service—preventive, curative and securative—first seeking out miserable children who had formerly been locked away in hamlets because the crippling had been thought to be a visitation from God, bringing them to the hospital for treatment, following up the after-care in their homes, and then training the disabled in trades, occupations and recreations by which to make them self-supporting men and women.

Here again, at what was then the Shropshire Orthopaedic Hospital but is now the Robert Jones and Agnes Hunt Orthopaedic Hospital, he would undertake incredibly long lists of operations, never less than twenty and often as many as thirty. We always started before 7.30 in the morning and went on until about 4 o'clock in the afternoon. These endeavours have occasionally been described since then, rather disparagingly, as " marathons of surgical exploit "; but this belittles and quite fails to understand the skill of organisation, and the skill of operative technique, that made it possible.

With two theatres, two anaesthetists and two most expert plaster teams, a cartilage would be removed within ten minutes, including the whole of the posterior horn and the peripheral fragment, in one theatre; and while the pressure crêpe bandage over copious wool-dressing was being applied the bowed tibiae of a child were being corrected by manual osteoclasis in the next theatre; and while the straightened legs were being most expertly plastered a boy's pes cavus was being tenotomised and wrenched with division not only of

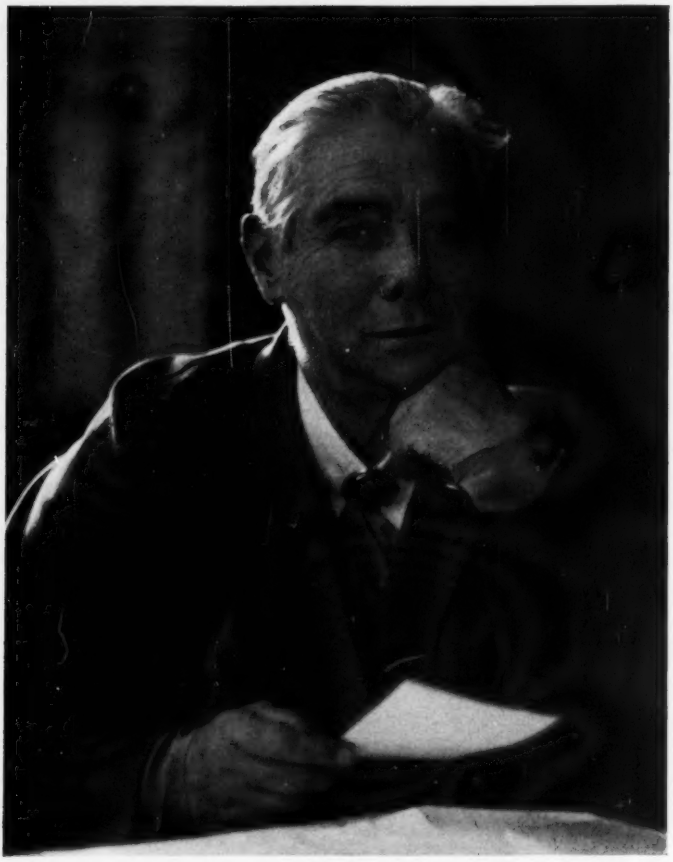


FIG. 4

AGNES HUNT

" It was in 1927 that Sister Hunt succumbed to the stimulation of Robert Jones and agreed that it was not enough to search out cripples and arrange hospital and after-care treatment. Crippled children, and young men and women, must be taught not only the joys of normal recreation but also the responsibilities of normal work. A retraining scheme was necessary. She wrote: I collected four boys, already training in the boot and blacksmith's shops, and two girls from the splint-making department, and solemnly informed them that they were the 'Shropshire Orthopaedic Training School for Cripples.' They were suitably impressed but were anxious to know what happened next. As this was more than I could tell them the meeting adjourned . . . In the next stage Miss Hunt tried to work

FIG. 5

ROBERT JONES

out the cost of surgical boots and wrote: Ten shillings for leather and two days of man's time at three pounds ten shillings a week plus 5 per cent profit equals —? Eventually I put X which I had been told meant an unknown quantity and went dismally to bed."

[This quotation illustrates the apparently carefree attitude of Agnes Hunt, which however, with the stimulus of Robert Jones, did succeed; so that to-day one million disabled and crippled people in Great Britain are re-established in useful employment. WATSON-JONES, R. (1948): Dame Agnes Hunt. Journal of Bone and Joint Surgery, **30–B,** 709.]

the tight plantar structures but also of the extensor tendons on the dorsum of the feet and the flexor tendons at the interphalangeal level—a technique that is being forgotten; and while those feet were having plaster-of-Paris applied to the tips of the toes to maintain correction of the clawed toes as well as of the clawed feet, a subtrochanteric osteotomy was being done to correct flexion-adduction deformity of the hip joint; and while the abduction-

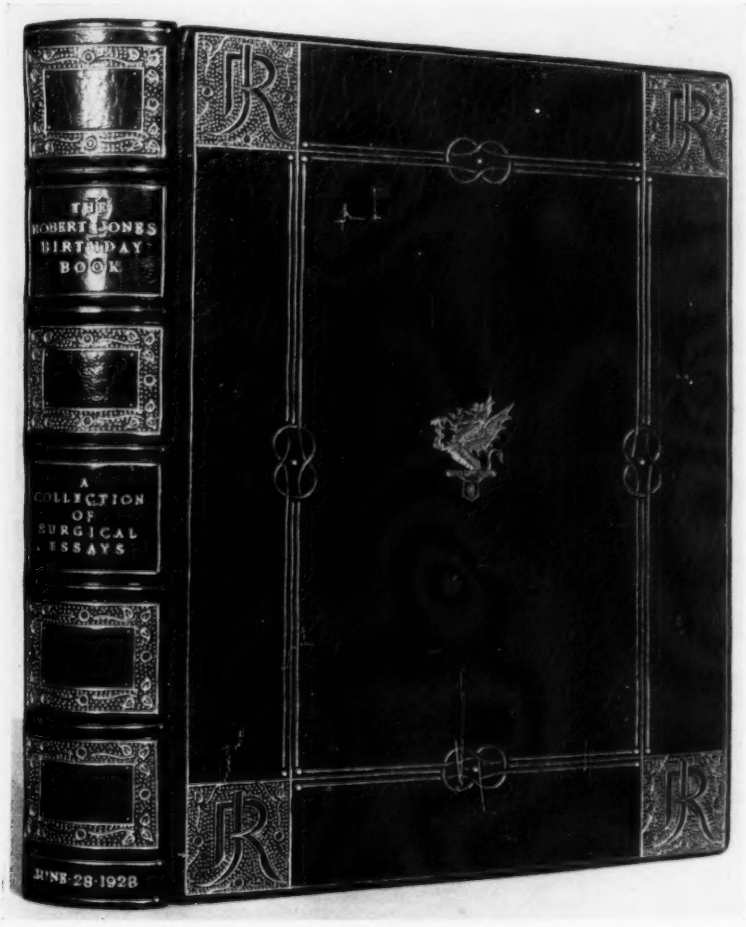


FIG. 6

ROBERT JONES BIRTHDAY BOOK

This is the binding of the original Robert Jones Birthday Book which was presented to him on his seventieth birthday in honour, dedication and respect from his students and disciples.

frame with skin-traction tapes was fitted, an old tuberculous spine was being fused with an Albee graft and the patient placed in the plaster bed already prepared, all within twenty or thirty minutes; with immediately thereafter excision and fusion of an arthritic knee joint in about fifteen minutes; and while the Thomas's splint was applied a tenotomy of the adductors in a child with congenital spastic paraplegia, and special instruction as to the exercises to be practised; and then reduction of bilateral congenital dislocation of the hips and the application

of plaster; always followed at about four o'clock by delayed cold luncheon shared by *every* member of the staff with Robert Jones and the chiefs, the house-surgeons, theatre sisters, nurses and orderlies—most of them seriously crippled themselves. Every one of us felt that since the very early hours of the morning we had done a good job of work; and Robert beamed upon us all.

FIG. 7

ROBERT JONES BIRTHDAY BOOK

Inside the front cover of the Robert Jones Birthday Book, published for him quietly and even secretly on his seventieth birthday, are the signatures of some of the disciples that had worked with him—but far from all.

If you are as breathless in reading that sentence as I am in writing it, you are not half as breathless as we all were in sharing the magnificent organisation and skilled surgery of Robert Jones. Of course, in his age, there were vast numbers of gravely deformed and seriously crippled children for whom the best operative treatment was a relatively simple procedure, occupying only a few minutes provided that the after-treatment was watched carefully. Since then, these gross deformities have not arisen because of the sustained and continued clinic

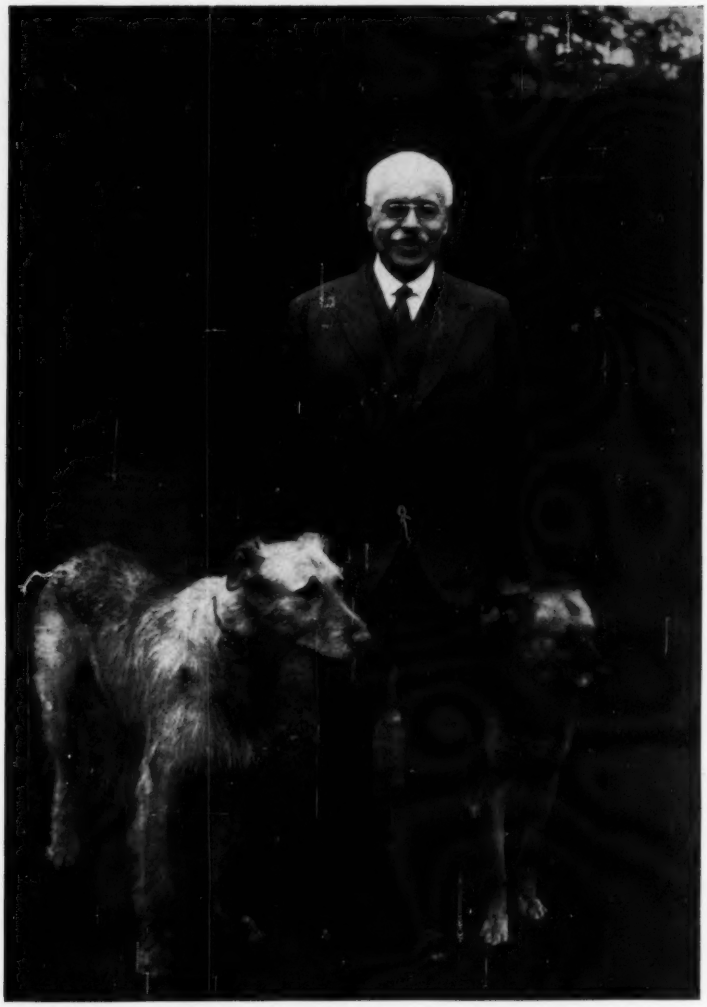


FIG. 8

Robert Jones with two of his dogs. He loved his Alsatians, Irish Wolfhounds and St Bernards. He was not a man for small dogs; he enjoyed the company of big dogs. But so also he was not a man of small ideas; he was a man of big ideas.

system of prevention as well as after-care (a truth that must be declared loudly when some Socialist Ministers of Health belabour us on the need for preventive as opposed to curative medicine). This skilled operative technique, superb organisation, and happy spirit of recovery was applied so generally to all the hospitals of this country that it would be invidious to try to enumerate them. Indeed there was no orthopaedic centre or great teaching hospital that he did not influence.

But it is difficult to know whether his contribution was greater to the relief of crippling in children in days of peace, or to the relief of disability in soldiers in days of war. Certainly the most dramatic was the vast organisation he developed during the first world war when the loyal endeavours of American and British surgeons were fused so happily. It may be true that Lieutenant-Colonel, soon Major-General, Robert Jones was quite likely to walk down Bond Street with his General's cap worn inadvertently back to front; he was a terrible soldier; but he was a wonderful friend.

We have thought of Robert Jones as a student and apprentice, as a general surgeon and young orthopaedic surgeon, as a gentle and kind protagonist of his uncle's staunch principles, as a pioneer in the development of preventive measures to avoid crippling, as a very great pioneer of rehabilitation after crippling, as an organiser of orthopaedic services, for civilians and for members of the Armed Services, as one who created the British Orthopaedic Association, the International Society of Orthopaedic Surgeons and the fusion of enthusiasm and friendship between the surgeons of British and American nations. What more can we say? We can say much more, and this is what matters most. He was a mild, lovable, understanding and simple man—equally at ease with a timid child, a truculent dock-worker, or a Royal personage.

He loved his dogs—the Alsatians, St Bernards and Irish Wolfhounds; he enjoyed boxing, and how strenuously he boxed himself; he was fond of cricket; he loved children, who soon learned to trust him; he was incapable of meanness, sarcasm or unjust criticism. He expressed displeasure by unruffled and restrained feeling which was felt rather than heard. He spoke ill of no man. He was kind, generous and encouraging to young surgeons but always with a cloak of anonymity. He was the very great friend of young surgeons, and few know how very great a friend he was to them.

May I quote one example of this? When I was very young, Robert Jones said that it would be wise for me to visit European orthopaedic centres and see the work of surgeons in other countries, and my reply was that much as I would like to, I could not afford it. Nothing more was said, but some weeks later he called for me and said that in rewriting his book on Orthopaedic Surgery he wanted a complete study of the literature on pes cavus and pointed out that this would mean travelling to London and spending a week or so there in the libraries. Having done it and presented to him the review (which in fact he never wanted—he had got it already) he said " It must have cost you something to stay that week in London; I will not pay for your lodgings but I will pay for a tour of the orthopaedic centres in Europe." This was typical of the disarming generosity of Robert Jones to young surgeons.

On June 28 next, there will be a Service in the Cathedral of Liverpool, on the centenary of the birthday of Robert Jones in 1857, near the foundation pillar in which are laid his ashes, the first ever to find a resting place here, above which is a stained glass window dedicated to *Service*. As long as the walls of that great Cathedral stand, there will shelter the token and memorial of a great servant of mankind who gave his gifts with generosity, with kindness and joy of heart. In the hearts and minds of those who came within the warm glow of his presence, and who learned humbly to love him, his spirit still lives.

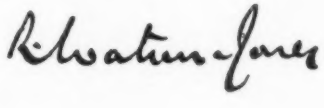


FIG. 9

The plaque over the Orthopaedic Department of the Royal Southern Hospital, Liverpool, reads: Sir Robert Jones Bart. 1858–1933. Honorary Surgeon Royal Southern Hospital 1889–1918. Founder of the Orthopaedic Department and of Modern Orthopaedic Surgery.

From the Rt. Honourable VISCOUNT MALVERN

P.C., C.H., K.C.M.G., F.R.C.S., M.D.

(Formerly Sir GODFREY HUGGINS)

Prime Minister of Southern Rhodesia
and first Prime Minister of the Federation of Rhodesia and Nyasaland

As one of those who worked under the supervision of Robert Jones during the 1914–18 war I would like to contribute my mite to this British volume of the *Journal of Bone and Joint Surgery*.

I first met Robert Jones, whom we all knew as R. J., when the Hammersmith Military Orthopaedic Hospital was opening up. I was sent there for a short course before being posted to the Pavilion Hospital at Brighton, which was being developed for wounded men whose limbs had been amputated but with stumps that were unsuitable for the fitting of artificial limbs. I soon got to know the greatness of this surgeon. He visited us from time to time, and he both criticised and inspired our work. A short time with him impressed us at once with his personality. For myself, it was soon realised that I was in the presence of one of those rare individuals who in any walk of life are entitled to the dignity of Master. He was not only a master of his art but also of human relations, and of the management of humans. He certainly managed his branch of the War Office in Whitehall!

To meet him on or off the job was a refreshing experience. Trained in a London school of Medicine, I had never before heard of him. I had even assumed that the Thomas's splint and Thomas's wrench had been named after the hospital of that name! Robert Jones brought his great knowledge and skill during the first world war to the benefit of the troops who were treated, and indeed to the everlasting benefit of the teeming millions living in England.

R. J., as I have said, was obviously a Master. Like all great men in any walk of life he created disciples; and through them his great gifts of "know how" in dealing with the deformed will live for ever. Mere knowledge of his art, great as it was, would not have produced a band of admiring and devoted disciples if he had not possessed fully that great kindness, charm and selfless spirit. Added to these virtues he possessed sympathy, tenderness and understanding in the handling of patients. Even more important, he was determined that his mission should go on when he passed. He did indeed succeed.

Malvern

From the Rt. Honourable The LORD COHEN OF BIRKENHEAD
M.D., D.SC., LL.D., F.R.C.P., F.A.C.P., F.F.R.

Professor of Medicine, the University of Liverpool

Although nearly forty years his junior, I was privileged to know Robert Jones as colleague, patient and friend. Others, and especially his disciples, can pay filial tribute to the greatest orthopaedic surgeon of his time, to his contributions to the surgery of World War I, and to the genius who did not need to take infinite pains but who always did. I write of him not only as one who loved his fellow men, but as one who loved being with his fellow men. He was a convivial member of a Liverpool dining club—the Y.Z. Club. To this he was elected in 1921 and remained a regular attender until his passing in 1933, two years after my own election to the Club. Much of the conversation there was anecdotal and Robert Jones was one of our most gifted raconteurs. May I, since they illustrate so well both the Puck and Peter Pan in his character, recount a few of the stories he told?

He had been called in consultation to a Lady C—— and, having seen and advised, was invited to take tea. He found himself among a roomful of Society dames. Promptly there bore down on him a lady whom he recognised as Mrs Asquith. She invited him to lunch. He accepted readily, adding, " Now that your autobiography is out I'll come without fear." " Oh! " said she, " You needn't bother about that; I only mention *really important people*."

C. J. Macalister, a physician and colleague on the staffs of both the Royal Southern Hospital of Liverpool and the Children's Hospital, accompanied Robert Jones on a yachting tour among the Western Islands of Scotland. Robert Jones rose one morning at an early hour before any of the other guests were astir and rowed ashore to a distant island where he came across a doubtful looking party of natives with whom he ventured upon conversation. He returned to the yacht and later in the day landed again at his island with his friends and Macalister, who heard that the wild and uncouth inhabitants were of the clan Macalister, and knew that one of the clan was the " greatest doctor in England." This had cost Robert Jones five shillings, being the amount he had to pay the islanders to take upon themselves a name to which otherwise they could never have laid claim.

At a luncheon given by Spanish surgeons to their British colleagues at an International Surgical Meeting in Madrid, after speeches had been delivered in English and Spanish, Frank Jeans, who was a junior surgical colleague of Robert Jones, spoke wittily in French, whereupon Sir Robert electrified the audience by orating in Welsh with great emphasis and conviction. He later revealed that he had, in fact, recited the " Men of Harlech."

A host of other stories spring to mind, which he told me when I was privileged to be his doctor. He was the most lovable of men, and I still cherish what is perhaps the last letter he ever wrote: " My dear Henry, God bless you! Gratefully; Robert Jones."

From JOEL E. GOLDTHWAIT, M.D.

Doyen of Orthopaedic Surgery in the United States of America

Robert Jones of Liverpool was first known to me in the early part of this century, long before he had been knighted by the King, and because of the reports that came to me regarding the way in which he handled fractures and joint damages. At that time I visited him in Liverpool and we spent a short time together. I saw his actual work, and heard about his first attempt to have an open-air ward for tuberculous children established a short distance south of Liverpool. We were often in correspondence after that but at the time of my presidency of the American Orthopaedic Association, which was held in Washington, Robert Jones with his wife and daughter, Hilda, came to this country and were my guests at our home in Milton, Mass., and after that in Washington. He went on to Canada as a guest of some of our Canadian representatives.

There were one or two other visits to him at Liverpool made by me; but with the first world war and the great number of wounded involving the extremities, he was forced into prominence and the King knighted him, so that he was trying to meet the great responsibility. With me, knowing that sooner or later our country must enter the war, I was in 1916 made Chairman of a Committee to organise orthopaedic men so that they could be available to help Sir Robert and to help the American troops as needed. At that time orthopaedic surgery meant very little in Great Britain and, as a matter of fact, there were not a great number of men calling themselves orthopaedic surgeons in the United States. But when we entered the war the first message that came for help from England was for twenty orthopaedic surgeons to help Sir Robert; and that at once established the place of orthopaedic surgery in the organisation there in your country. After that the men assigned to that branch were treated in such a way that they were never transferred to any other line of work. They were held in sanctuary.

The same thing also occurred in my own country. Less than a month after the United States entered the World War I, I personally sailed from New York with twenty men, reasonably well trained in orthopaedic principles, to be turned over to Sir Robert Jones for distribution among his hospitals. I personally went along at that time and worked with Robert, studying his methods so that later on, when I was assigned to definite work with our troops in France, we were in fairly close contact. After that there were a number of other young men of our group who were assigned to Sir Robert's work. They not only helped him, but when the stress came for our own needs, some of the men who had been trained with him became very valuable in our work, which was kept on with great intimacy.

Following the duties, and after the death of Lady Susie, he came to this country and was seen and entertained by me. There was always the closest intimacy between Sir Robert and myself.

Joel E. Goldthwait

From Professor EDWARD GALLIE

F.R.C.S., F.R.C.S.(C.), F.R.A.C.S.

Gold Medallist, Hunterian Professor, Moynihan Lecturer, Royal College of Surgeons of England

Past President of the American College of Surgeons, American Surgical Association, Royal Canadian College of Physicians and Surgeons, and the Canadian Orthopaedic Association

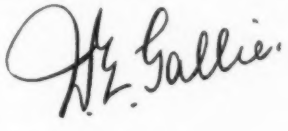
There is nothing I could appreciate more than to take part in doing honour to Sir Robert Jones. While I would enjoy saying words of appreciation of his high qualities as a man, as a surgeon and as a leader, I shall leave this to those who were more intimately associated with him than I. But I am qualified, perhaps more than anyone now in practice in Canada, to record what he did for our Canadian soldiers, and what his ideas have done for the Canadian people since that time.

It was fortunate for Canada that, before the war, Clarence Starr of Toronto had completed his training in general and orthopaedic surgery in England and had developed a great admiration for Robert Jones of Liverpool. Dr Starr never seemed to tire of recounting what he had learned in Liverpool and repeating that, in all his experience with surgeons in New York, in Canada, in Germany and in Great Britain, he had never met the equal of Robert Jones.

As a result of this friendship, which fortunately was mutual, Clarence Starr at once made contact with Jones when he joined the Canadian Army overseas. This was soon after Major Jones recommended the establishment of special hospitals for the care of lesions of the nerves, ununited fractures, wounds involving joints, and amputations. Such a hospital was promptly established at Buxton in Derbyshire for the Canadian Army and, under the skilled hand of Colonel Starr, they rapidly became efficient. When this unit had been firmly established Colonel Starr was recalled to Canada to help to develop there the system which had been brought to such excellence in England by Robert Jones.

The result has been the establishment in Canada of hospitals equipped to the *nth* degree for taking care of veterans. Just as in England, the Department of Veterans' Affairs has taken over the manufacturing of artificial limbs and has set up a factory in connection with a centrally placed hospital to which all amputation cases are sent. As a result, the surgeons in charge of these patients have gained great experience, and have been able to determine what are the best types of amputation for men who must return to civilian activities, and what is the best type of prosthesis. Thus, contrary to surgical opinion in many places, the Syme amputation is held in high regard in Canada.[1, 2]

I recall a visit of inspection he made to the Granville Canadian Special Hospital in Buxton in 1918, and the satisfaction he expressed that the Canadian Army had adopted his suggestions. I cannot help thinking how pleased he would be to-day if he could see the hospitals now spread across Canada which were designed on the principles he recommended in 1915.



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From PHILIP D. WILSON, M.D.

Director of Research, the Hospital for Special Surgery, New York

AN AMERICAN APPRECIATION

It is an honour to be permitted to write a few words of tribute in memory of that great man, Sir Robert Jones, on the occasion of the 100th anniversary of his birth. William James once wrote that a man has as many personalities as he has friends, because each one sees him differently. Robert Jones had thousands of friends; but no matter in what guise he may have appeared to each of them individually, all would have agreed upon his qualities and accomplishments.

That he was a deft operator and a skilful surgeon there can be no doubt. Praise of him in this field was sung far and wide. He was known as a great and stimulating teacher. Hundreds of doctors and nurses gave thanks for what they had learned from him. He devised surgical operations which still bear his name. He more than fulfilled his duties in the various hospitals and clinical posts to which he had been appointed, helping his patients and winning their love while at the same time attending to a fabulous private practice in a manner that gained the devotion of hosts of others. He found time to write scientific articles for medical journals, to collaborate in the preparation of a text-book, and to organise and edit other works. In addition, he gave many hours of his precious time to public and governmental duties.

He did all this in the field of orthopaedic surgery. He not only practised orthopaedic surgery; to a large extent he made it. When he entered this field of work it scarcely existed as a speciality and there were only a few practitioners who busied themselves chiefly with mechanical corrective measures by means of braces or plaster-of-Paris. Surgical operations scarcely extended beyond subcutaneous tenotomies or osteotomies. When he left, it was a respected and flourishing surgical speciality with hundreds of outstanding practitioners. He was drawn into this field of work by his uncle Hugh Owen Thomas, who had a large practice among the teeming population of Liverpool and who became noted for his development of mechanical methods for the treatment of fractures and of tuberculous and other diseases of the joints. Robert Jones gained much from his association with his uncle, but he also gave much because his own devotion to the principles he learned from him extended Thomas's teachings and augmented his reputation. Robert Jones's contribution to the association was the development of surgical methods to supplement or to replace the mechanical methods when a more certain cure or a better result could be obtained. After the death of Thomas, Robert Jones took over the practice and continued to work at 11 Nelson Street. His reputation grew, and his consulting rooms became a Mecca for medical visitors among whom were many Americans.

With the outbreak of the first world war, Robert Jones gave up practice to serve his country. On account of his reputation as an outstanding surgeon and his large experience in the treatment of fractures, his help was soon sought to make plans for the care of the wounded. Experience gained in the early battles of the war quickly showed that compound fractures of the extremities would constitute the most common and serious problem among the survivors of machine-gun fire and high-explosive shells, and that very many of these wounded would die unless better care could be provided for them, close to the place where they had been injured. In dealing with this problem, Robert Jones was on familiar ground, and he solved it by the introduction of the Thomas's splint. This was to be applied by the stretcher-bearers at the place of injury, and to be used to protect the extremity, and to prevent pain and shock during the transportation of the wounded to the forward surgical hospitals, and later during the journey of the soldier to the base hospital. The use of this splint for the transportation of those wounded with compound fractures was extended through the British

Army, and later to the American Army, and was responsible for the saving of thousands of lives and many thousands of limbs.

This contribution was great; but it was only one of many made by Robert Jones. His vision reached far beyond the matter of providing the best immediate care. It extended to the need for final care and reconstructive surgery and for rehabilitation of the crippled soldiers as civilian wage-earners. He foresaw the need for special orthopaedic centres at home in Britain for the wounded who would never be able to fight again. Here they would be given the best surgical care and facilities and would also be helped to regain function in stiff joints and weakened muscles. There would also be made available services for recreation, education and vocational training to aid in the rehabilitation of the whole man and his reorientation from military to civilian life.

In this area he encountered what at first seemed an insurmountable obstacle: a shortage of experienced orthopaedic surgeons. But he was not to be defeated. There was a small nucleus of young surgeons. To a large extent he had inspired them to enter orthopaedics and they had gained considerable experience in their own localities. These men he placed in key positions in his hospital centres. He recruited other young and promising men to train under them, thus establishing what we in the United States of America would now consider the equivalent of a resident training programme. But the inflow of the orthopaedically wounded was then going on at such a rate that it far exceeded the capacity of the orthopaedic centres. There was an increasing need for larger facilities and more orthopaedic surgeons. New hospitals could be built, but the big question was how to supply an experienced staff.

This was the time when Robert Jones made another of his great contributions—the forging of a bond between American and British orthopaedic surgeons which will never be forgotten. Leaders among orthopaedic surgeons of the United States at this time foresaw that their country would soon be drawn into the war, and that the responsibility of treating those wounded in the spine and extremities would fall upon members of their speciality. How could they prepare for this day better than by sending a group of surgeons over to work and learn from their British colleagues before the American Army arrived?

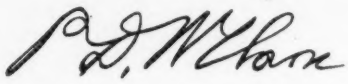
So the British need was dovetailed with the American desire to learn and gain experience in order to prepare for the time when their services would be needed by their own people. Everything was arranged and made as easy as possible by Robert Jones. The first unit of American orthopaedic surgeons, led personally by Joel E. Goldthwait, landed in Liverpool, and was welcomed by him early in 1917. The United States entered the war in April of the same year. The members of this unit were quickly assigned to orthopaedic centres in England and Scotland; then a second group arrived and were similarly placed. The American surgeons worked harmoniously with their British colleagues and many deep and lasting friendships were established.

It was this old link between British and American orthopaedic surgeons that inspired the organisation of the American Hospital in Britain which worked first in Basingstoke and later in Oxford during the more recent great war. This was essentially a civilian orthopaedic unit which was sent over to be of medical assistance during the period when the United States was still neutral.

The American Expeditionary Force built up more quickly than anyone had anticipated, and early in 1918 Colonel Goldthwait, who in France was directing the Orthopaedic Section of the Army Medical Corps, had to begin drawing his surgeons back from Britain for work with the American Force where they certainly gave an excellent account of themselves. But by this time Robert Jones had replacements ready, and the withdrawal was made without damage to his own orthopaedic organisation.

Someone once said that the greatness of a man is to be judged by whether or not his ideas or accomplishments live after him. Judging from this standpoint we can say that Robert Jones still lives as a great pioneer in orthopaedic surgery, exemplifying surgical skill,

new ideas, the importance of teaching and above all the need for a comprehensive vision extending from the first step in the treatment of a crippled person to the complete restoration of that individual as a self-sufficient and wage-earning member of the community. He was indeed a pioneer both in orthopaedic surgery and in the rehabilitation of the crippled. The mere fact that we take time to celebrate the 100th anniversary of his birth some twenty-four years after his death, confirms his greatness.



From LEO MAYER, M.D., F.A.C.S.

Director of Surgery, Hospital for Joint Diseases, New York

It was in April of 1913 that I had my first opportunity to visit Robert Jones. I had completed a year of orthopaedic training in Munich under Fritz Lange where, under his guidance, I had begun my research of tendon surgery. Lange was the leading German orthopaedic surgeon, chief of a large well-conducted clinic. Much as I admired him I realised after only a few days in Liverpool that Robert Jones had opened a new world to me. For the first time I saw atraumatic surgical technique applied with a deftness and respect for tissues, so perfect that to this day it has remained my criterion for excellence in surgical workmanship.

Robert Jones performed most of his operations on private patients in improvised operating rooms in so-called " nursing homes " with only one nurse to assist him. His equipment was the simplest. Yet, under these conditions, he could remove a torn meniscus in ten or twelve minutes with a minimum of trauma. The incision, which I still use, was made through a towel to avoid skin contamination. The operator's fingers never entered the joint. A few strokes with the scalpel to free the meniscus anteriorly, a quick jerk on the clamp at the proper moment to release the posterior portion, a twist of the knee to expose the posterior attachment, another stroke of the scalpel and the meniscus was out! The tissues were sutured with meticulous accuracy, using a Reverdin needle. The surgeon never seemed to be hurried; but not a single motion was wasted. The operation was over before it seemed to have begun.

In contrast to these nursing homes, where Robert Jones seldom performed more than one or two operations at one time, were his operative clinics at the Royal Southern Hospital. Here his schedule for a single session usually included from twelve to twenty operations. There would be for example four or five arthrotomies, a few tenotomies or tendon transplants for deformities from poliomyelitis, reduction of congenital club feet, osteotomies of the femur, subtrochanteric or supracondylar osteotomies. These were done with a special saw which could be inserted through a stab wound, the bone section being completed in a few minutes, the deformity corrected and then an appropriate splint applied. Plaster-of-Paris was never used. There was a splint ready for every occasion. In conducting these clinics, as in the individual operations, he never seemed to be hurried. He always had time for a few words of explanation to his audience or for a joke, and I never heard him use a cross word to his assistants. They responded to his courtesy by giving him loyal and expert co-operation.

But great though he was in the operating theatre, he seemed to me to be even greater in his clinic at 11 Nelson Street. Here he saw patients from all over the world. The fame of his diagnostic and therapeutic skill had spread to every land. His ready tact enabled him to present these cases to visiting doctors who were thus privileged to learn from the great variety of orthopaedic problems presented. Only as a rare exception our host would say " Sorry I can't show you this lady; she has an interesting hip but modesty forbids its exposure." Sunday mornings were particularly stimulating. It was then that Robert Jones saw patients without charging any fee. Many were Welsh miners with whom he spoke in their native language.

He treated their sprained backs with cautery and generous applications of paper, bound on with muslin bandages to form a firm support. Their dislocated shoulders were reduced, even after three or four weeks, with a special ring device that permitted traction to be applied by his powerful doorman who liked nothing better than assisting his master. Unreduced Colles's fractures yielded to his powerful grasp. With a word of warning to the patient: " This will hurt a bit," he gripped the displaced bones as if in a vice and then with a sudden force the distal fragments of the radius were brought into alignment with the shaft and, before the astonished patient knew it, two splints had been applied, holding the fragments in perfect reduction. And through it all Robert Jones kept beaming his warm smile and giving words of encouragement.

To those who did not have the chance to meet this unique man I should like to give a picture, however inadequate, of his geniality, his charm, his simplicity, his humour, his generosity and his genius for friendship. His cheerfulness was infectious; he was like a boy in his enthusiasm, and in his love for a prank or a practical joke. At the same time he had the maturity and wisdom of a Hippocrates. Above all, he had a sympathy for the disabled and the will to help them which prompted him to organise and establish the rehabilitation centres for the war-cripples and for disabled children. To this great work he devoted the closing years of a long life of service dedicated to the good of mankind.

Among the many great men I have met none stands out as vividly as Robert Jones. None has had as strong an effect in moulding my life as he has had. For no other do I cherish the same degree of admiration and esteem. I gladly acknowledge him my orthopaedic master and guide.

Leo Mayer.

From Sir FRED E. PRITCHARD, M.B.E., LL.D.

Formerly Judge of the High Court of Justice, Queen's Bench Division

Her Majesty's Judges when on Circuit are the representatives of the Sovereign in the County in which the Assizes are being held.

For this reason, and to avoid the embarrassment which might result from close contact with prospective litigants and witnesses at the Assizes, it has not been their custom to attend functions other than public functions at which their presence might reasonably be expected—and then only in the Robes of their Office.

In the days when I was practising at the Junior Bar in Liverpool and was in chambers with Arthur Probyn-Jones, however, an exception was regularly made in the case of Sir Robert Jones at whose house in Belvedere Road the Assize Judges were always ready and happy to dine privately.

To many of these dinner parties it was my privilege to be invited as Arthur's friend and it is one of my most vivid recollections that to walk into Robert Jones's drawing room when he was there was to walk into the presence of one whose greatness was not confined to the field of surgery in which he excelled, but of one who was great, irrespective of Calling, and who would have achieved greatness in whatever field he had been called.

Fred Pritchard.

From Sir THOMAS FAIRBANK
D.S.O., O.B.E., M.S., F.R.C.S., M.CH.ORTH.(HON.)

King's College Hospital, Great Ormond Street Hospital for Children
Past President of the British Orthopaedic Association

When I was a young man Robert Jones was regarded as the outstanding surgeon in orthopaedics, not only in this country but throughout the world. He did brilliant pioneer work and, moreover, he was a man of exceptional charm and kindly personality. These gifts and qualities resulted in his great influence on the development of orthopaedic surgery, particularly among younger men. Naturally I decided that I must try to see him at work. When he heard that I was to spend a few days in Liverpool, in the hope of being present during his hospital visits, he promptly invited me to stay with him. This was an honour that I accepted with alacrity and gratitude.

On this my first, but by no means my last, visit to his home I found that Dr Joel Goldthwait of Boston was also there. What a delightful lesson it was for a young man to listen to these two surgeons discussing surgical problems. The next day we were driven to Baschurch where Robert Jones had a full day's work. There I met Sister Agnes who later was honoured by the King and became Dame Agnes Hunt. She had converted the outbuildings of her house into the first Children's Hospital in this country at which open-air treatment was combined with surgical measures in dealing with surgical tuberculosis. Later this work was transferred to what is now so rightly known as the Robert Jones and Agnes Hunt Orthopaedic Hospital, Oswestry.

What a joy and privilege it was to see Robert Jones at work. I remember a child with spinal deformity. He asked me to examine the patient, and he watched me with a kindly but critical eye. I think that I came through the ordeal reasonably well, having already done some work as a clinical assistant at the National Orthopaedic Hospital with A. H. Tubby with whom Robert Jones collaborated in the publication of at least two articles near the end of the last century.

After a full morning spent in seeing cases Robert Jones proceeded to the so-called operating theatre. There were many operations and manipulations, even up to twenty or thirty in one session. We spent another morning at Nelson Street in Liverpool, where Goldthwait and I were allowed to see him dealing with private patients in the same thorough and kindly way that he had shown us at Baschurch.

After the first world war Robert Jones came to London regularly one day each week, seeing private cases in a consulting room. I was often able to seek his help and again I experienced the kindness and consideration for the opinion of a young man.

In 1929 a meeting was held in Paris to consider the formation of an International Society of Orthopaedics and Traumatology. There were many American and Continental surgeons. It fell to my lot to play a part in the election of Robert Jones as the first President of the Society. There was of course great competition; but with the aid of my friend Murk Jansen of Leyden, of international repute, Robert Jones was elected. In his first presidential address he said: "I have derived my greatest inspiration from a friendly and close association with the younger generation, especially those who are but little influenced by tradition. They often correct or modify our sometimes crusted views or by clash of intellect encourage introspection and force us to revise our premises. Often they merely strengthen us in our views."

Robert Jones not only taught the world how affections of the bones and joints should be treated, but by the charming manner in which he dealt with younger men and encouraged

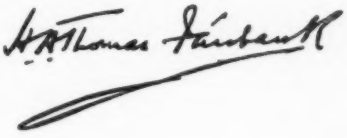
them to think for themselves, he did much more than others to cultivate their ideas. More than one of his contemporaries said: " You never heard a harsh word said about Robert Jones."

During the first world war he was responsible for the introduction of the Thomas's splint for the treatment of severe wounds of the leg, especially if the femur was fractured. The application of the splint, even at many Regimental Aid Posts in the front line, avoided suffering and saved many lives.

It is significant that Robert Jones was a general surgeon in his earlier days and he always took a broad view. It must be agreed that he was chiefly responsible for the acceptance of the principle that the treatment of fractures, joint injuries and affections of peripheral nerves is part of this orthopaedic field of surgery.

Two of his distinguished associates I remember particularly and with gratitude, namely—Dr C. Thurstan Holland, the well known radiologist of Liverpool, and Sir John Lynn-Thomas of Wales. I should add that it was indeed an honour to be invited to assist Sir Robert in examining candidates for the degree of M.Ch.Orth (Liverpool) during the first two years that it was established. Two of the candidates we passed, namely Reginald Watson-Jones and Bryan McFarland, have done much to maintain the reputation of the Liverpool School of Orthopaedics.

Lucky are we whose lives overlapped that of this great man.



From BRYAN MCFARLAND
M.D., M.CH.ORTH., F.R.C.S.

Professor of Orthopaedic Surgery, University of Liverpool
Past President of the British Orthopaedic Association

It is difficult to write something new about Robert Jones. Everyone who knew him will speak of his charm, friendliness and inspiring personality. The story is well known of his early days with Hugh Owen Thomas, and many people remember his " middle days " as assistant surgeon at the Royal Southern Hospital. He was third in the general surgical team, the order being Alexander, Newbolt, Robert Jones. Professor Herbert Williams, who remembers these days very clearly, because he was a house surgeon at that time, also remembers some of the visitors—the Mayos, Albee, Horowitz, Lucas-Championnière, Murk Jansen.

It may not be realised how much general surgery owes to Robert Jones. He did not much like it, and delegated most of that work to Armour who was, as it were, a second string to all three honorary surgeons. It is interesting that Sir Robert visited the Royal Southern Hospital on only two afternoons a week, and nevertheless during his visits found time to join in a game of cricket in the courtyard with the residents and students. Although he did not then have a personal assistant he could always rely on assistance from all the residents off duty who would go readily and happily to his operating theatres and out-patient sessions just to watch and give a hand if they got a chance (" *Eheu! fugaces* ").

Dame Agnes Hunt came each Saturday to out-patients, with her batch of children from her home in Baschurch. The out-patient department was always crowded, but the Baschurch

children were seen first. Then Sir Robert would call out " any patients from North Wales? " After they had been seen, patients from Preston and Lancaster and the North, and then from Crewe, were examined before the Liverpool patients were seen.

In the end Sir Robert had a house surgeon entirely to himself. The first holder of this post was Alwyn Smith who, with Armour, used to finish off the operating list after the major work had been done, though, even during the operating sessions, various unofficial assistants were given such jobs as moulding club feet and changing splints, Robert Jones walking round all the time and seeing how they were shaping.

Just as Robert Jones was one of the first to use an x-ray machine, one year after it was invented, he was one of the first to have a motor car, which was described as a very small noisy Rover (1906–08). The noise had an advantage because it was heard from nearly a mile away so that the assistants were always on the spot when Robert came through the hospital door!

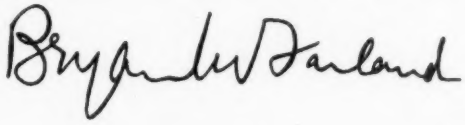
I delight in some personal recollections. In 1928 when correcting nurses' examination papers in orthopaedics I found one quotation from Sir Robert relating to the long tedious illness of a patient with tuberculous disease of the hip. The nurse's comment was " one of the main aims of the nurse should be to encourage the patient and keep his pecker up "—this being one of Sir Robert's favourite phrases, which always caused amusement across the Atlantic. In reply to my short note recording this observation he sent a delightful handwritten note: " I shot an arrow in the air; it came to earth I know not where."

In September 1930 my first child was born. I was a very obscure young orthopaedic surgeon, hardly aware that Sir Robert had noticed me very much, being as I was well down in the list of his assistants. But three weeks after the birth of my son Robert Jones came to my flat with a bunch of grapes and asked to see my wife and her child. While he was with us one would have thought that there was only one baby in the world in whom he was really interested—my boy.

It would be a mistake to be deceived by Sir Robert's easy and rather jolly manner—there was always strength of purpose, determination and organising ability behind it. On one occasion in the Royal Southern Hospital after a resident surgical officer had presented a case so badly that he had placed his chief at a disadvantage, Robert Jones said: " now I will race you up the stairs "; and as they went up he said: " if that ever happens again you are *out*." Again I remember the mother of a little boy with pseudo-hypertrophic muscular paralysis. Not unnaturally the earlier treatment had not produced any very satisfactory results. I watched with great interest what Sir Robert would say to the mother. Having enquired carefully and found that the condition was not worse, his observation was: " I always find that if this condition does not get worse you have to be grateful, and you have every reason to be very pleased and very hopeful."

Another memory is of watching this great surgeon manipulate the club feet of babies. The shape of Robert Jones's hands is well known. They were not, I would say, the classic type of operating hands—but they were marvellous manipulators. They seemed to become plastic and almost to blend with the material on which they were working—almost an accompaniment to the tune which he always hummed while things were going well.

Probably one of the most pleasant memories, and one which is shared by our Editor, is of Robert Jones conducting, with the assistance of Sir Thomas Fairbank, the examination for the M.Ch.Orth. degree of Liverpool University. If anyone failed in that examination it was not Sir Robert's fault. Even to be failed by these two great men would be a distinction.



From Sir MAX PAGE

K.B.E., C.B., D.S.O., M.S., F.R.C.S.

St Thomas's Hospital, London

Past Vice-President of the Royal College of Surgeons of England

Looking back I am struck by the little attention that had been paid, outside Lancashire, before the 1914–18 war, to Robert Jones's work on the treatment of injuries of the extremities.

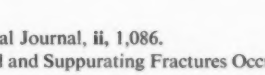
To me he had been an orthopaedic surgeon distinguished as the author of work on paralytic conditions in childhood. I knew of the value of the Thomas's splint and the abduction frame for tuberculous joint disease, but not of their application to fractures. I think the same was true of most young surgeons serving in the army in 1914, who like myself had been educated in the London Schools. Our seniors were certainly responsible for major fractures, but for the first decade of this century their main interest had been devoted to the rapid advances in abdominal surgery. The South African War had not afforded much experience in the management of infected injuries.

In the autumn of 1914, after the fighting about Ypres, surgeons in France were in desperate difficulty over the treatment of infected fractures of the lower limb both at the front and at base hospitals. This difficulty was reflected by the grave mortality and the high amputation rate. Robert Jones soon became informed of this deplorable state of affairs. In letters and articles published in the *British Medical Journal* in 1914 and 1915, his methods for the management of compound, open and infected fractures were soon adopted. I still think that the greatest benefit Robert Jones conferred on the British fighting services stemmed from his two articles in the *British Medical Journal* (1914–15).[1, 2] They certainly resulted in the first forward steps in the management of septic fractures in the wars of this century.

My personal contacts with R. J. dated from his appointment to St Thomas's Hospital in 1919. He never did much work there, and soon handed responsibility to that capable deputy Rowley Bristow. I saw more of him and his pupils at the Ministry of Pensions Hospital at Hammersmith where he established a fine unit for the late treatment of war casualties. He was delightful to work with, brimming over with enthusiasm, and with a passionate interest in the welfare of his patients.

He was a plump, short and vivacious man, with never any tendency to domineer—in dress attractively careless whether wearing uniform or not. In social life he was effusively friendly, always appreciating good food and drink. Perhaps, rather oddly, he was a keen follower of professional boxing.

He was indeed a most likeable man, brimful of energy even in his sixties, and able to inspire others in his methods and ideals. It was his personality and tact, coupled with great persistence, that had so profound an influence upon the surgical organisation of this country.



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[2] JONES, R. (1915): Remarks on the Mechanical Treatment of Compound and Suppurating Fractures Occurring at the Seat of War. British Medical Journal, **i**, 101.

From GEORGE PERKINS, M.C., F.R.C.S.

St Thomas's Hospital, London

Past President of the British Orthopaedic Association
Formerly Chairman of the British Editorial Board of the Journal

When I first met Robert Jones I was a mere boy in medicine. It was on an English summer's afternoon at a strawberry tea-party in Dame Agnes Hunt's garden. Maybe it was the setting; but I at once succumbed to the Welsh charm. Robert Jones became an idol, at whose shrine I have never ceased to worship. I remember the anger I felt on hearing another surgeon say about menisectomy: " Robert Jones *and I* make this incision." What impertinence!

To bear goodwill towards all men is not such a difficult task. To be in receipt of goodwill from all men is accomplished by only a few. And Robert Jones was one of the few. He tamed the general surgeons and many of the more famous—Stiles, Moynihan, Hey Groves who became his ardent supporters. However, it is not as a paragon of virtue that we write about him in a scientific journal on the centenary of his birth. When the memory of his charm has been obliterated, the name of Robert Jones will still live as an orthopaedic surgeon.

The surgeons of to-day do not do all the things that Robert Jones did. We no longer include a Thomas's wrench among our instruments; and we no longer use a Thomas's knee splint for either kind of fractured patella. But that his methods were old-fashioned does not detract from his greatness. Einstein is, perhaps, a better physicist than Newton; but whose fame is greater? It has been said that Robert Jones's greatness depended on his expounding to the world the brilliant ideas of H. O. Thomas. Certainly he did that. Certainly that was a mighty deed. Anyone who has tried knows how difficult it is to convince anybody about anything in orthopaedic surgery. But the fame of Robert Jones is founded on something much more solid. He was an orthopaedic surgeon by instinct. He always knew what to do and when. With a frozen shoulder he did not encourage movement " until the patient could lie on that side." " Early active movement which causes no pain can seldom be harmful and is often beneficial." " A joint may be assumed to be free from arthritis when even one of its movements is free." " A bandage is not a mere means of keeping a dressing in position, but should be regarded as a modified splint."

Speaking of breaking down adhesions he said: " the most striking results are often brought about in the case of the knee if we remember one very important point and that is to secure the full rotatory range." He also said: " wounds in the flexure of the elbow should be treated with the elbow extended "; " to increase shoulder movement the patient should get his hand on the wall and creep up with his fingers until the elbow, arm and side are flat against the wall "; " there is one golden rule regarding fractures of the elbow—they should all be treated with the elbow fully flexed with the single exception of the olecranon which requires full extension "; " early passive movement is harmful "; " the importance of Pott's fracture lies not so much in the break of the fibula as in the disturbance of the axis of the ankle joint which is liable to follow "; " hallux rigidus is a source of considerable trouble among recruits." All of these are orthopaedic platitudes; but who invented them? This sample was gathered from a small book on " Injuries to Joints " written by Major Robert Jones, R.A.M.C.(T.) in 1915. The repeater of a platitude may be a bore; the inventor is a genius.

Much of present-day therapy derives unconsciously from the wisdom of Robert Jones. Much as we would like to match his brilliance we are doomed to play second fiddle. It is a small comfort to have something in common with the Great Man. Robert Jones was very fond of kippers; so am I.

George Perkins

From ST-J. D. BUXTON, F.R.C.S.

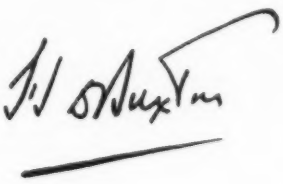
King's College Hospital, Shepherd's Bush Hospital

Past President of the British Orthopaedic Association

In February 1919 at the Special Military Hospital, Shepherd's Bush, Sir Robert was enjoying a day with the staff and a number of us new boys who had returned from overseas and were still in uniform. He did two cartilage operations, being assisted by Max Page and Rowley Bristow. I held the end of a retractor at long range. R. J. sat on a large towel drum on the floor. In getting up and down he never failed to demonstrate the advantage of the flexed knee bent over the end of the table.

His charm to patients and to the nursing staff was an example to us all. So seldom did he express adverse criticism. With enthusiasm and encouragement to the young men who were inspired by him to become orthopaedic surgeons he talked of logic, surgery, remedial workshops—and also of the tragedies of war. He was happy when speaking of children in country hospitals and of the need for association between orthopaedic surgeons of the United Kingdom and the United States. Of course he talked of dogs! Then he would be taken off to enjoy a good luncheon.

Sir Robert's magnetic figure was in the centre of the stage during the time that the British Orthopaedic Association had its teething troubles. Also shall we remember Alton in 1922? Unison was achieved, perhaps as a result of the cricket match with disabled boys at Treloar's, or more likely from the after-dinner speech at the Swan Hotel which ended with a chorus of cheers and R. J.'s typical finale: " Now Willie (Trethowan), we shall be delighted if you will entertain us at that piano, although it appears to require some reconstructive operation." At Manchester in 1925 his presidential address to the British Orthopaedic Association was entitled " Remarks on the training and activities of the Orthopaedic Surgeon." It was a speech of wisdom and it made a great impression upon me. He urged that orthopaedic surgeons should educate the public, and the authorities, to stamp out tuberculosis and rickets. He said that his own treatment of club foot differed little from the treatment used by Hippocrates two thousand years before, and said that even the Temple of Aesculapius had open-air wards! Yes, indeed he was a great man.



From ALAN S. MALKIN

C.B.E., M.B., F.R.C.S., F.R.C.S.E.

Harlow Wood Orthopaedic Hospital

Former President of the British Orthopaedic Association

Shortly after the Armistice which concluded the fighting in the first world war some young medical officers from the front, of whom I was one, were sent back to Great Britain for training in military orthopaedics at the Special Military Surgical Hospitals which had been developed by Robert Jones at important centres. The idea was that these young surgeons, when ready to do so, should replace the American surgeons on whom the responsibility for

the work of these hospitals had largely fallen. Many of the Americans had come to Great Britain because of their high personal regard for Robert Jones but they naturally wished to return to America as soon as possible when the fighting had ceased.

I was attached to the Special Military Surgical Hospital at Birmingham under Naughton Dunn and it was here that I first met Robert Jones. But long before this I had been greatly impressed by hearing about his work and reading his writings.

As a young Regimental Officer in 1915 I had issued to me a small book—an Oxford War Primer written by Robert Jones and entitled *Injuries to Joints*. This is how its intention was described in the preface: " The object of this little book is to attempt to give some help in the diagnosis and treatment of injuries of joints in a form which will be useful to the hundreds of practitioners who have left the quiet paths of private practice for the more eventful career of military surgery.

" The injuries they may have to deal with may vary from a twist or sprain due to a fall on rough ground to a complicated gunshot wound. For the minor injuries the ordinary advice given in peacetime, namely rest, is not enough, as the soldier must be returned fit for duty in the shortest possible time, while the more serious injuries are outside the ordinary experience of general practice."

At about the same time he wrote a series of articles in medical journals, many of which were subsequently published in a little book called *Notes on Military Orthopaedics*.

These two books, *Injuries to Joints* and *Notes on Military Orthopaedics*, had an immediate success and were widely circulated throughout the Allied armies. They showed his great concern for the wellbeing of the injured.

Their success was due to many factors. It was due to the burning enthusiasm of the writer, but it was also due to the intrinsic worth of the advice given. This advice was of practical value—it was easily understood—it was based on sound common sense—it was written in an easy readable style with a minimum of words—it was well suited to its readers and it met an urgent need.

It is difficult to realise after so long a time what a profound effect the advice of Robert Jones had on the salvaging of the wounded throughout the entire war. An early instance of this was shown by the change in the treatment of fractures of the femur. At the beginning of the war, for fractures of this bone a long Liston splint or a rifle splint was used in the first stage but by the end of 1915 Robert Jones's advocacy of the Thomas's splint had resulted in its employment in many units and it was soon afterwards adopted throughout the entire front.

The consequence of this change was that patients arrived at the casualty clearing station in an infinitely better condition and shock was no longer so serious. Statistics worked out in 1916 showed in one Army area that before the Thomas's splint was used 80 per cent of the compound fractures of the femur died, but with immediate fixation on a Thomas's splint the mortality rate fell to 20 per cent.

But it was not only in his writing and speaking about methods of treatment that his influence was used—he used it also in striving to provide the conditions for applying the methods he advocated. That meant setting aside or creating special hospitals for all those wounded requiring prolonged orthopaedic treatment. More than that he used his influence to ensure that as far as possible the morale of the wounded and a desire to work was maintained. This is what he said in the *Notes on Military Orthopaedics*: " By the time a soldier has passed through various phases of recovery from septic wounds in several different hospitals and is finally transferred to an Orthopaedic Centre for treatment to correct deformity and restore the use of injured joints and muscles, his spirit is often broken. The shock of injury, frequently in itself severe, followed in succession by a long period of suppuration, and then by a wearisome convalescence, during which he receives treatment by massage or electricity, or by monotonous movement with mechanical apparatus of the Zander type, too often leaves him discontented with hospital life, its monotonous round of routine, and its long periods of idleness.

" In the Orthopaedic Centre he finds his fellow-patients busily engaged in employments in which they are doing something, and it is not many days before he asks for a ' job.'

" In the Military Orthopaedic Hospital at Shepherd's Bush alone, out of 800 patients about 500 are employed at some regular work, which fosters habits of diligence and self-respect, and converts indolent and often discontented patients into happy men who soon begin to feel that they are becoming useful members of society and not mere derelicts.

" Thus, when the preliminary stages of operative and surgical treatment are over, there is a steady gradation through massage and exercise to productive work, which is commenced as soon as the man can really begin to use his limb at all. If his former trade or employment is a suitable one he is put to use tools he understands, otherwise some occupation suitable for his disability, and curative in its character, is found for him.

" Men with stiff ankles are set to drive a treadle lathe or fretsaw. If put on a treadle-exercising machine the monotony soon wearies the mind, but if the mind is engaged not on the monotony of the foot work, but on the interest of the work turned out, neither mind nor body becomes tired.

" Men with defective elbows and shoulders find exercise and mental diversion in the carpenters' and blacksmiths' shops. If their hands and fingers are stiff, working with a big swab to clean windows or with a paint brush is a more interesting occupation than gripping spring dumb-bells.

" Those of us who have any imagination cannot fail to realize the difference in atmosphere and *moral* in hospitals where the patients have nothing to do but smoke, play cards, or be entertained, from that found in those where for part of the day they have regular, useful and productive work.

" Massage and exercise is no longer a mere routine: it all fits in and leads up to the idea of fitness—fitness to work and earn a living and serve the State in an economic sense, even if not to return to the regiment and fight once more in the ranks of the Army." Here was modern rehabilitation clearly explained.

His feeling about the wounded man was epitomised in what he said in 1917: " From the beginning of the War, I have been convinced that the most serious problem that faces us as a Nation, is the question of how to deal with the disabled, discharged soldier. . . . Until an individual interest is taken in a man, from his entrance into hospital until he enters civil life, our material duty will have been left undone. I have lived and worked long enough to realise that the aim and not the end, is the main thing. When the end comes and peace is declared, the cry will be for War Memorials. Is not now the time to decide on these? You do not want to wait till the dead are forgotten. Are our memorials to be spiritual or material, living and permanent, or dead and cold? For my part, I have no hesitation in saying that marble or brass has no re-echoing voice to me. My feeling is that the heroic spirit that sent our beloved dead to their end should be reflected in an equally heroic effort on our part to make and keep the nation efficient."

During the war after reading his writings and hearing so much about his work I had built up in my mind a picture of Robert Jones. I imagined him to be a tall, austere man, almost prophetic looking. Shortly after I was posted in 1919 to the Birmingham Special Military Surgical Hospital I met him for the first time and I found my picture was quite wrong. He was not very tall, he was not austere and he had not the look of a prophet. Instead he had a benign look and a welcoming smile for all. He was interested in life in all its aspects and in many forms of sport. He was one with whom almost everyone felt instantly at ease.

I met him again at the first British orthopaedic meeting I attended in 1919. He was unassuming, gentle and willing to help anyone. After this I met him on various occasions. He was always enthusiastic in the cause of the cripple and would respond to any appeal.

During the war a great change had taken place in the attitude of people to crippling conditions largely due to the work of Robert Jones. They felt that crippling conditions

could be cured and that they should no longer be accepted as inevitable. Robert Jones felt that this new attitude, this change in public opinion must be utilised for the benefit of the crippled. In 1919 with G. R. Girdlestone he published a paper in the *British Medical Journal* proposing a National Scheme which comprised preventive treatment and training of cripples and potential cripples.

The plan was simple. It was to divide England and Wales into districts each with a fully equipped orthopaedic hospital in the centre and grouped around it a number of out-patient clinics which were under the control of the staff of the central hospital.

In 1923, like the citizens of some other cities, a few of the citizens of Nottingham who were members of a small cripples' guild, wanted to do something for crippled children. Robert Jones was approached. He came to Nottingham and took part in a conference in which laymen and doctors were included, and drew up a report. As a result, it was decided to advertise for an orthopaedic surgeon to develop a scheme on the lines of his national plan, and, on his recommendation, I was appointed. He came and spoke at my first annual meeting in Nottingham. As we made progress, he watched our efforts and encouraged us, and, when finally Harlow Wood Orthopaedic Hospital was to be opened, he came and took part. But his interest did not stop there. He agreed to be the Senior Consultant of the Hospital and on several occasions during the next few years he visited it and with me did a complete round of the wards. If he wished to suggest some alternative treatment, he would not condemn what was being done, but he might ask if you had tried this or that method which he had found a good one. You felt you had a real friend, with vast experience, behind you, and what a comfort that is when you are young and feeling rather isolated.

During the last ten years of his life he did not spare himself. He visited various parts of the country and, by personal influence, writing and speaking, did all he could to popularise his scheme. Seventeen centres with associated clinics were established by the time of his death.

On January 14, 1933, Robert Jones died and was mourned as a public benefactor. How can we assess what he had done?

In the College of Surgeons of England one's mind instinctively turns to the work of John Hunter and, although so much separated them both in time and character, he and Robert Jones can be compared. The one, John Hunter, had a bias to what has been called scientific surgery; while the bias of the other, Robert Jones, was to practical surgery. It is said that the one had few friends and was never personally attractive; whereas the other had a magnetic personality with friends old and young in every station of life, and on them he had a great influence. Yet both achieved success. Both were caught up when young by a great enthusiasm, and this enthusiasm remained with them to the end. There would have been between them a fundamental agreement. I can hear Robert Jones echoing such words as these of Hunter's: " The man who judges by general principles only, shows ignorance. Few things are so simple as to come wholly within the general principle. We should never reason on general principles only, much less practise on them, especially when we are or can be, master of all the facts. But when we have nothing else but general principle, then we must take it for our guide." Or these (though perhaps in better English): " There never was a man who wanted to be a great man, ever was a great man."

Robert Jones's concern was never with greatness, but always with work to be done. I felt the mainspring of his life was a burning desire for physical and social justice for the disabled, and a great feeling of responsibility. His was a dedicated life. It is not too much to say that what Hunter did for surgery Robert Jones did in the more limited field for orthopaedic surgery, but he knew that that was not enough. His interest was in surgery but more in what surgery meant to every man, woman or child. His interest was in the wellbeing of the whole patient. He felt that each individual, however disabled, should be a happy, useful member of the community and it was the achievement of his life that he made this possible for countless

numbers. In his life he did much to conquer disability. He left many of his friends, old and young, to carry on the fight against it.

What has been said of John Hunter can truly be said of Robert Jones. He did not make an epoch—he founded a school. On the foundation that Robert Jones laid, what structure has been raised in the last twenty-five years? In prevention we have seen the advent of antibiotics; a rapid decrease in the number of those suffering from tuberculosis; an almost complete elimination of rickets and a hope of overcoming anterior poliomyelitis; and the establishment of fracture and orthopaedic services in nearly all hospitals. These are great achievements.

We have seen great advances in the treatment of paraplegics for whom there is now the possibility of living independent and self-supporting lives. The rehabilitation services provided for the disabled are almost fully comprehensive: though small at present the potentialities are great. They provide for:

1. The injured skilled man who needs practice in his skilled work before he can return to his pre-accident job.

2. The permanently disabled man who, in spite of his disability, can be trained in a new job in which he will be on an equality with the fit.

3. The man too disabled to take his place in industry who needs work in a Remploy Factory or a sheltered workshop.

4. The man who can work only at home and who can get help in this from the local authority.

There are in many areas local associations for the welfare of the physically handicapped who can and will help in all rehabilitation problems.

What then can we as orthopaedic surgeons do in this continued struggle against disability? May I suggest to my younger colleagues a few things that can be done:

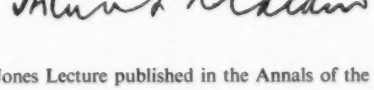
1. Maintain our work as members of a craft guild at the highest pitch of efficiency. This may mean for some of us, particularly if we work at peripheral hospitals, giving up the treatment of certain types of case which are comparatively rare and which require the specialised investigation or treatment that can best be provided by a team at an orthopaedic centre. This is not easy for the young enthusiastic surgeon but it is most important if progress is to be made.

2. Assist constantly in the instruction of all who should be concerned with the early signs of disability, especially in children. It may be remembered that before the last world war Professor Putti of Bologna as a result of propaganda had been able to treat over 700 cases of congenital dislocation of the hip in children under one year of age. Of these 94 per cent showed excellent or perfect anatomical functional results. In no other way could this be achieved.

3. Take a keen interest in the physical education of children and the prevention of postural defects.

4. Bring to the notice of the disabled the facilities available for them not as forlorn last hopes but as something valuable provided to assist them back to independence. A disability must be very severe to prevent a specially trained man from doing useful work, given courage and determination which we can help him to maintain.

In many ways we can play our part " to make and keep the nation efficient " and in so doing we shall be carrying on the work of Robert Jones in conquering disability.

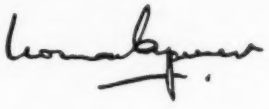


Part of this contribution is reproduced from the Robert Jones Lecture published in the Annals of the Royal College of Surgeons of England, February 1957.

From NORMAN CAPENER, F.R.C.S.

Director, Princess Elizabeth Orthopaedic Hospital, Exeter

Probably the last of the pilot schemes in orthopaedic development in which Robert Jones was actively engaged was the one in Devon. Here he found two keen supporters in Dame Georgiana Buller and Brennan Dyball—a distinguished son of St Thomas's Hospital. In 1928 a half-completed orthopaedic hospital at Exeter was hastily filled with children for the day of inauguration by the Duke and Duchess of York, as they then were. It was named by them after their daughter, the young Princess Elizabeth. In the fun of this rather premature party Sir Robert joined with characteristic enthusiasm and modesty. Four years later he came to see me at work, the hospital's first orthopaedic surgeon appointed after an apprenticeship in the United States. Sir Robert was no inquisitor but he was a student of mankind. After twenty-five years the memory is still vivid of a kindly and very wise man who played with the children, chaffed the terrifying Georgiana, and entered with keen interest into the thoughts and plans of a young man whom he made feel, at least for that day, was *his* teacher. A few months later Sir Robert died.

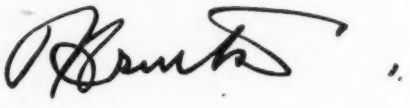


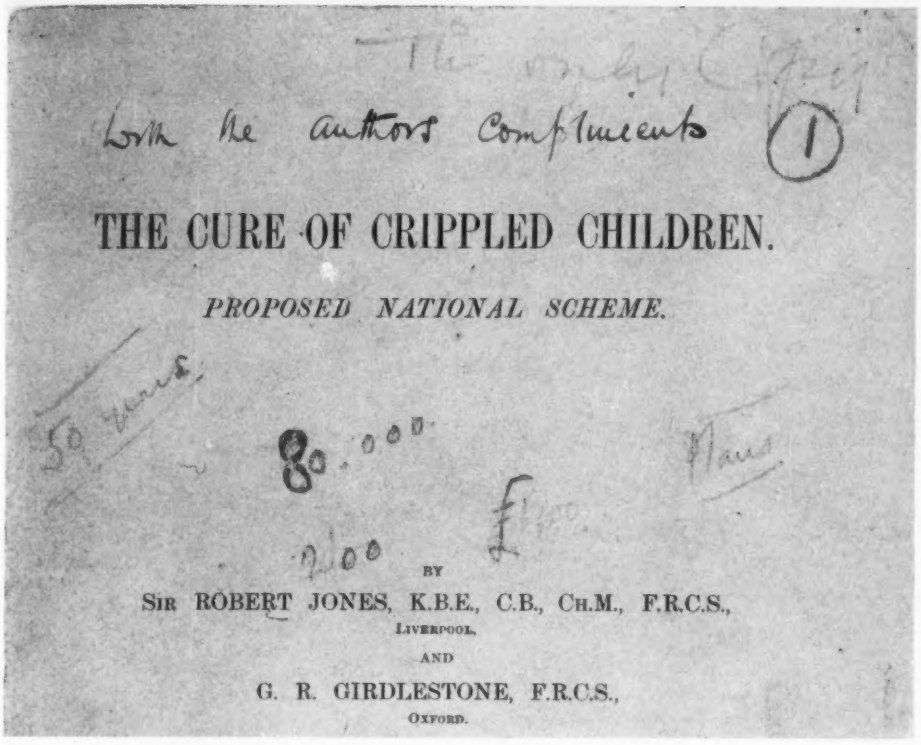
From JOSEPH TRUETA, Chevalier de la Legion d'Honneur
M.D., M.D.(HON. BUENOS AIRES), F.R.C.S.C.(HON.), F.R.F.P.S.(GLASGOW), F.R.C.S.

Nuffield Professor of Orthopaedic Surgery, University of Oxford

I am so pleased that the name of Girdlestone will appear in the Robert Jones Centenary Number. I firmly believe that the greatness of any innovator can best be judged by the quality of his pupils, and to have had, like Robert Jones, so many outstanding workers in the field of orthopaedics is a real measure of his immense size. Naturally, Girdlestone with his crusading spirit and his early association with the Master at Baschurch must be considered to have a place in an issue as important as this one.

It might be of interest to readers of the Journal to see the title page of the National Scheme for Crippled Children put forward jointly by Robert Jones and Girdlestone and a few lines of the proof as annotated by Robert Jones.





With the author's Compliments

THE CURE OF CRIPPLED CHILDREN.

PROPOSED NATIONAL SCHEME.

BY

SIR ROBERT JONES, K.B.E., C.B., CH.M., F.R.C.S.,

LIVERPOOL,

AND

G. R. GIRDLESTONE, F.R.C.S.,

OXFORD.

GENERAL CONSIDERATIONS AS TO TREATMENT.

Under present conditions some of these children die, and of the remainder most become cripples. Many are fully curable, almost all can be benefited; but an organization to provide early and well-directed treatment is necessary.

The country has, so far, made no real effort to face the problem. The great need for hospital provision for cases of surgical tuberculosis has indeed been recognized by Government under the National Insurance Act (1911), but no comprehensive scheme has been brought forward. Here and there orthopaedic hospitals, or orthopaedic departments of general hospitals, exist as a result of voluntary effort, but these are only capable of dealing with a small percentage of the cases. For the immense majority there is no hospital accommodation, nor can they hope for adequate treatment. The task is beyond the scope of the general hospitals, for it is impossible for them to provide the necessary conditions, which should include ample bed accommodation in open-air country hospitals. It is characteristic of orthopaedic surgery that an operation is often not an end in itself, but one link in a chain of treatment; moreover, by early treatment and progressive orthopaedic measures operation can in many cases be avoided altogether. Further, there is, as a rule, no period of natural convalescence, but, on the contrary, in the case of most deformities a persistent tendency to relapse long after complete correction. For these reasons a long stay in hospital with continued careful corrective treatment and

From JOHN MENZIES, C.B.E.

Until recently Secretary-Superintendent of the
Robert Jones and Agnes Hunt Orthopaedic Hospital, Oswestry

Everyone who had the pleasure of knowing and working with Robert Jones cherishes the memory of a stimulating and wonderful experience, and I am proud to pay humble tribute on the occasion of the centenary of his birthday. Countless thousands of those who benefited from his work and teaching would have wished to pen this contribution.

Few men in peacetime or in war, for injured civilians and wounded soldiers, made so great a contribution to our people as did Robert Jones. It is not for me to write of his influence in the world of orthopaedic surgery which has resulted in widespread benefits to humanity. But even as a secretary one could not fail to see the transformation produced by his vision and influence. No longer do we see the untreated crippled child—the saddest of all spectacles. We saw the injured and disabled restored to happy life.

I first met and worked with Robert Jones when I became secretary of the Hospital at Oswestry that bears his name. He was the first surgeon to appreciate that the problem of the physically disabled was not solved simply by treating patients in a central hospital. He realised that any plan would need the ancillary services of clinics for prevention and after-care, supported by voluntary organisations. He said: " Without voluntary help the plight of the cripple would have been pathetic." Rehabilitation, resettlement and re-education were his principles, and it was in this sphere of administration that one marvelled at his enthusiasm and grasp of detail. His wise counsel and friendly guidance proved to be invaluable, for he had that rare facility of stimulating everyone concerned with his own conception of the job in hand.

The tablet to the Memory of Robert Jones erected in the Goodford Memorial Chapel in the Hospital at Oswestry bears the words " Great Surgeon—Greater Man." As a layman serving him, it was in this latter capacity that I knew Sir Robert. His cheerfulness, his consideration for the welfare of others, his human understanding was outstanding; as well as his humour by which for example there would be no appointments while the Test matches were being played or while he was judging puppies, or looking after his old Welsh pony, or shooting duck, or sharing the duties of his son-in-law Frederick Watson as Master of the foxhounds. When Sir Robert died the world lost a much loved illustrious benefactor and the hospital and staff at Oswestry its guide, philosopher and friend. As the years go by "Great Surgeon—Greater Man" seems to fit more perfectly.

From GORONWY E. THOMAS, F.R.C.S.

Orthopaedic Surgeon, Royal Liverpool United Hospital

Lecturer in the University of Liverpool

I have in my possession a few of Robert Jones's case notes and among them I found a typewritten copy of one of his letters to a doctor which I feel is very interesting in that it illustrates an aspect of his life that is often commented upon.

Dear Dr Thomas,

I have seen Humphrey Jones to-day and I think, on the whole, he is doing nicely. . . . I have also had his exercises reviewed.

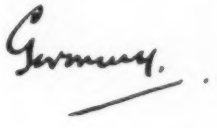
I wonder how Menai Bridge looks now. I have vivid recollections of it because, as a boy of about 12 or 13, I was at boarding-school there under the care of a weird character with a huge head and little else excepting a great mathematical brain. His name was John Thomas. I spent a very happy time there and remember clearly the village in those days. More particularly do I remember a little confectioner's shop, on the right-hand side on crossing the Bridge from the Caernarvonshire side, where they sold the most succulent and delightful jam tarts. Such is memory! In all my wanderings I have never been able to taste such tarts as they sold there for, I think, ½d. each! I also recollect very well the grocer's shop which maintained a prominent position at the head of the village and where we used to take blackberries after picking them so that they might make us jam. In the grounds of Pen y bryn there were some rocks and, looking back now, they would seem to me between 15 and 18 feet. I used to take a great delight in jumping off these rocks on to the soft green below. I suppose the blackberry jam, the jam tarts and the high rocks have been exaggerated by time. Years afterwards I visited the old school, where—if I am not mistaken—the well known physician, Dr Roberts, lived. One day, if I am in the neighbourhood of Menai Bridge, I shall have to take a stroll and see if I can recollect all these early spots, and, more particularly, the Calvinistic Chapel, where sometimes we used to have six sermons on Sunday.

With kind regards,

Yours sincerely,

Robert Jones.

I thought that you might perhaps regard this letter as an item of interest for inclusion in this commemorative volume.



A CHRONOLOGICAL LIST OF SIR ROBERT JONES'S CONTRIBUTIONS TO SURGICAL LITERATURE

(1883): Ununited Fractures of Humerus, Radius and Ulna, Successfully Treated; Remarks. Lancet, **ii,** 703.
(1883): Fractures of Humerus, with Dislocation at Right Shoulder and Elbow. Lancet, **i,** 727.
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AMPUTATIONS

The ablation of any of our organs, and particularly the external ones—be they limbs, nose, eyes or ears—has an unpleasant sense of finality which, as well as the cosmetic blemish, is recognised by all patients and should be more appreciated by all surgeons. There is, however, no dispute that at this stage in the development of " cancer " therapy amputation is still a procedure which often ensures the most useful and lasting survival and allows eventually the least unpleasant demise from metastasis elsewhere. Again, amputation is sometimes the most desirable treatment in severe congenital abnormalities, as has been so clearly demonstrated by, amongst others, our leading authority on amputations, Leon Gillis, in his recent Hunterian Professorship lecture (1956).

When faced with the *fait accompli*—the limb already amputated for congenital deformity, injury or disease—it is remarkable what can be done to help the unfortunate patient. Elsewhere in this number we have an admirable survey by Zanoli of the place of the Krukenberg-Putti technique following loss of the hands, which has also been advocated so convincingly and modestly by Kallio of Finland since the last Russo-Finnish war, and from several British authors with the benefit of an experience of the management of no less than 80,000 amputees from what may be regarded as our national amputation centre at Queen Mary's Hospital, Roehampton. This centre owes much in its conception to the vision and inspiration of our great pioneer in orthopaedic surgery—Sir Robert Jones—to whose birth centenary this number is dedicated. There were, and are, many supporters—Muirhead-Little, one of the foremost authorities of the early days of the century; Littlejohn of forequarter amputation fame; Gordon Gordon-Taylor, the doyen of hindquarter amputation now reaching towards his hundredth operation; Elmslie and Rocyn Jones, persistent advocates of Syme's amputation in the 'twenties and 'thirties; Jenner Verral, George Perkins, Dudley Buxton—and in these days Gillis and the distinguished writers in this issue of the Journal.

It is interesting to note the swing of opinion in favour of end-bearing stumps—the Syme's and the Stokes-Gritti or modifications of them. Many of us, convinced by the arguments and the results of our Canadian colleagues—Gallie, Harris, Le Mesurier, to name but a few—have long held similar views.

It is, however, in the field of injuries that there is often controversy amongst surgeons. Is a prosthesis likely to be more useful than a distorted limb if it survives? Is it more economic for the patient to remove the damaged limb now? It is salutary to remember that amputation was regarded as a final choice by such orthopaedic pioneers as Robert Jones and Elmslie. The latter put the matter with the delicacy of his day and age: " if one has a foot (or a Syme's stump) with reasonable skin sensation and capable of bearing weight relatively painlessly it is possible to escape alive at night from a burning house, for there is no need to delay in order to apply an artificial limb! " There are of course other reasons for wanting to leave one's bed at night, particularly with increasing age!

We must, therefore, continue to emphasise that despite all the technical improvements in the construction of artificial limbs—and they are many and to be welcomed—it should be a rule that amputations should never be undertaken immediately after injuries in which the blood and nerve supply of the distal portion are adequate for useful function of the extremity. It is no doubt a cliché to repeat this, but like many important truths it tends to be forgotten in the propaganda for " newer and better " prostheses. Indeed almost the only exception to this rule—which during the second world war resulted in a minimal number of amputations in the Royal Air Force—is the severely lacerated finger. Though viable, its bones, joints, tendons and nerves may be so extensively damaged that in spite of the great advances in recent years in hand surgery it is certain to be stiff and useless. Careful consideration

of all the factors will sometimes make amputation of the digit the best primary treatment because patients show a remarkable reluctance later to have a stiff, livid, painful and useless appendage removed. This is an attitude dictated not only for reasons of compensation but because of the natural revulsion against mutilation, as the writer has emphasised in his opening sentence.

Let us then remember that increasingly reconstructive surgery includes, as much or more than amputation, the restoration of limbs which though not always completely normal have that boon of mankind—the abilities to feel and to grasp with our hands and to reach and to feel the ground with our feet. H. OSMOND-CLARKE.

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OSTEOCHONDRITIS DISSECANS

The etiology of osteochondritis dissecans has given rise to much speculation, and in recent years the world literature has contained an increasing number of case reports bringing to light previously unknown features of the condition. Indeed the manifestations reported differ so widely from the previously accepted conception of the classical lesion that it has become more and more apparent that widely differing cases are concerned, and that the term osteochondritis dissecans merely serves to indicate a broad similarity between one case and another. No hard and fast criteria can be laid down as being necessary to justify the diagnosis, but it is usually accepted that the diagnosis can be properly applied to any case in which a portion of the articular surface, not necessarily containing bone, separates or attempts to separate by a process of gradual and " dissecting " extrusion.

There can be no doubt that in some cases—particularly in the knee and ankle—trauma, athletic or occupational over-use, or similar mechanical factors play an important part and may indeed be the sole cause of the condition. Even in these cases it is doubtful whether the lesion can ever be properly described as a simple osteochondral fracture. The fact that the lesion invariably shows itself on a convex articular surface and never on a concave one, although it remains unexplained, is also a clear indication that some mechanical factor must underlie the development of the lesion. Even when a constitutional factor is known to exist, as in bilateral affection of the elbow, it is always the dominant right arm that is more severely affected. However, mechanical factors alone are quite insufficient to explain the occurrence of multiple and often symmetrical lesions, familial and hereditary cases, and the association with dwarfing and endocrine disorder. White, in this number of the Journal, records three patients in whom the multiple lesions of osteochondritis dissecans were present in association with shortness of stature and fairly convincing evidence of endocrine upset. Local mechanical factors may determine the joints affected and the sites of the lesions, but the constitutional factor is obviously predominant. It is also interesting that in White's case there appears to be an association with osteochondritis of the spine which has also been noted by previous authors.

It is interesting to note the age incidence in different cases. Affection of one or both hip joints may occur in a young child. The lesion is radiographically identical with those seen later in life. There is a strong tendency to spontaneous healing of the lesion with conservative treatment, or even without treatment. It is also noticeable that when the constitutional factor seems to be preponderant, as shown by multiple joint involvement, symmetrical involvement of the knee caps and familial cases, the age incidence tends to be lower than in cases in which a single joint is involved. There appears to be a stronger case for the operation

of some constitutional factor in affection of the elbow or elbows, and the age incidence is much lower, the onset being almost invariably before growth is complete. By contrast, osteochondritis dissecans affecting the knee joint commonly arises after growth is complete and without any evidence of any constitutional cause.

With regard to treatment, there has been an increasing tendency towards a more conservative approach than was once popular. If the lesion can heal spontaneously in a young child, why should our treatment not be directed towards inducing healing of the lesion in older children and young adults by surgical or non-surgical means? In the past it has too often been accepted that separation of the detached fragment or fragments is inevitable, and surgeons have anticipated detachment of the loose fragment by carving it out, even at a stage when the overlying articular cartilage, although softened, remains unbroken. This sort of surgical excision is only justified if it is clear that there can be no hope of repair. There are occasions when the existence of a crater on the joint surface is less likely to lead to symptoms and subsequent arthritis than the persistence of irreparable detachment and fragmentation of cartilage and bone. The recommendation of Guilleminet and Barbier that excision of the lesion in the hip is the treatment of choice may be appropriate to the cases they describe, but it would be quite inappropriate in young children, and in many cases in older children and adults in whom symptoms are minimal or absent.

The practice of multiple drilling of a partly detached fragment has been employed for many years, although not much publicised. Used in the appropriate case it can lead to radiological evidence of healing of the lesion. An alternative procedure is to use a small peg bone-graft, countersunk in a small hole in the articular surface. Smillie has now, with great success, carried conservative surgical treatment a stage further by replacing in the crater a loose body which has already become detached and is lying free in some other part of the joint. It is doubtful whether such a policy is really necessary when the lesion lies in the so-called classical site on the medial condyle close to the intercondylar notch, but in other cases, which are just as common, in which the crater lies on an important weight-bearing surface of one or other femoral condyle, restoration of the articular surface is highly desirable and Smillie has shown that it can be achieved. It will, of course, take some time before the limitations of the method can be defined, but in the meantime Smillie's contribution serves to remind us of the possibilities of conservative surgery.

His suggestion that an extension of the principle could lead to the use of homografts of bone and articular cartilage is an interesting speculation, but it would be premature to consider this as a practical surgical possibility until the possibility of survival of such a graft has been proved experimentally. NORMAN ROBERTS.

AMPUTATION STUMPS

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It was not until the latter part of the first world war and the years that followed that it became possible to make a collective survey of such large numbers of amputations as 40,000 which resulted from that war. This survey became possible only because the Government organised a limb service under medical control for the prosthetic treatment of war amputees, which in later years has widened its activities to cover all civilian amputees in the country treated in hospital in the National Health Service.

The large number of patients studied in those early days were mainly young servicemen who lost their limbs as a result of gunshot wounds, immersion, and trench foot. During that study it became clear to the medical staff that there were certain levels of amputation in the lower and the upper extremity that were good and better than any other levels, and those came to be termed " ideal." The reason why they were ideal was because not only were they best able to activate the best type of limbs and fittings then available, but also because in doing so they stood up to the stresses and strains of limb wearing and seldom broke down surgically (Mitchell 1943). The main object of all concerned then, as now, was to provide a stump that could best function with an artificial limb, and which would not require further surgical attention. The ideal lengths of those days were as follows: above the knee, ten to twelve inches (25–30 centimetres) from top of greater trochanter; below the knee, five and a half inches (14 centimetres) from the medial edge of the tibial plateau; above the elbow, eight inches (20 centimetres) from the tip of the acromion; below the elbow, seven inches (18 centimetres) from the tip of the olecranon. These lengths, for years accepted in this country, were agreed by the Prosthetic Working Party Sub-Committee of the Brussels Treaty Organisation at their meeting in Utrecht (British Medical Journal 1953).

The experience in dealing with amputees since the 1914 war, through the 1939 war, and in handling some 40,000 civilian amputees to date, has not caused us to modify our views that the sites mentioned above are " ideal " when conditions render it necessary to perform an amputation through the shaft of the femur, tibia, humerus, or radius and ulna. We have been led to believe, however, that in individual cases it may not be necessary to adhere to these specified levels of amputation if there is a surgical alternative for operation as opposed to bone section at a lower level. This view is strengthened by the improved design and fitting of limbs to unconventional stumps; such limbs now match in functional efficiency those supplied for stumps of ideal lengths. Our present views upon amputation levels are as follows. *Above the knee*—If an amputation through the femoral shaft must be performed and conditions permit of a ten- to twelve-inch stump in an adult, that stump length remains the ideal. If the level of bone section were to be determined from the line of the knee joint rather than from the trochanter the measurement would depend upon the length of the whole femur. For instance, if the femur were seventeen inches long, bone section to provide a twelve-inch stump would be performed five inches above the line of the knee joint. In children and young adolescents the division of bone would be as low as possible. Bone section below the level of the shaft, such as transcondylar amputation, still fails to provide long-lasting stumps in most cases in this country, and are not advocated. For thigh amputations the anterior flap method with posterior transverse scar has proved the best. The least possible injury should be inflicted upon the sciatic nerve. Muscles may be divided at or below the level of bone section. Deep fascia should be sutured separately. When it is not possible to provide a

stump of ideal length, good functional results are obtained with a femoral stump as short as seven inches, and reasonable function has been obtained in stumps of less than five inches provided they are not bulky. If a thigh prosthesis cannot be fitted but a tilting table is essential, it is still desirable when conditions permit to retain the head, neck and greater trochanter. When conditions demand a disarticulation at the hip, as in the case of a high amputation for neoplasm, the posterior flap method is preferred.

Disarticulation at the knee—When bone section of the femur is not essential and conditions permit of a disarticulation at the knee, disarticulation (with or without excision of the patella) is strongly to be recommended, especially for old persons and children. For the skin flap an incision with convexity downwards should be made about four inches below the level of the knee joint. This operation offers the advantages of speed, avoidance of shock, and preservation of muscle sheaths. From the prosthetic aspect an excellent limb can be fitted and control of the shin is possible. Full and true end bearing is a great advantage and facilitates rapid rehabilitation; and few of these stumps have failed even after years of limb wearing. Under certain circumstances, therefore, this becomes an ideal stump.

Below the knee—The ideal length of tibia for a definitive amputation continues to be five and a half inches. Stumps longer than this tend to show signs of intolerance with limb wearing, though their longevity is sometimes increased by full ischial bearing.

Equal anterior and posterior flaps have proved most satisfactory; the distal anterior extremity of the tibia should be bevelled off and the fibula divided an inch higher than the tibia. Excision of the fibula is not recommended unless it becomes abducted, as happens on occasions in short stumps. Stumps measuring one and a half inches have functioned well in a below-knee limb provided they have no redundant tissues (Thomas and Haddan 1945). In earlier years such a stump would have been immobilised and fitted with a kneeling limb or amputated above the knee.

The Syme amputation—This operation met with disfavour after the first world war for a number of reasons which can be summarised as follows. Many patients never reached the stage of limb fitting and may have been subjected to operation under unfavourable conditions. Many underwent re-amputation within five years of the end of the war and many failed to tolerate full end bearing for more than a few years. The fact that limbs in those days provided for full end bearing contributed to the failure of many of these stumps, as did the introduction of the modified Syme's amputation with division of the bone at a higher level (Shelswell 1954).

In 1929 limbs were provided to allow for partial or full tibial bearing, and these have been used ever since. Re-amputations after the Syme operation are now uncommon.

It is felt that a perfect Syme's amputation performed under good conditions on a man provides an ideal stump, and such amputations are known to have lasted for forty years or more. For young boys and girls a Syme's amputation is indicated when possible as the operation of choice, to avoid the prolific overgrowth of bone that is frequently observed when the bone is divided before the epiphyses have fused.

The place of the Syme amputation in a girl or woman remains controversial. For many such patients the cosmetic result is very important. With a Syme prosthesis the disablement is always noticeable, and some women have regretted that the amputation had not been performed below the knee, for the prothesis can be matched perfectly with the sound limb.

Amputation above the elbow—The ideal humeral stump remains eight inches, not because circulatory defects sometimes arise in longer stumps, but rather because such a length provides all the leverage needed and enables the best type of limb to be provided, with the best functional results. This length is also ideal in cases of amputation for complete brachial plexus palsy, in which cases it is recommended that the shoulder be arthrodesed in slight abduction.

Shorter stumps give good functional results but there must be at least an inch of stump below the lower level of the anterior axillary border. In some cases this necessary inch has been obtained by division of the lower fibres of the pectoralis major. The retention of the

head of the humerus is always advisable when it is practicable, even though there will be no functional stump.

Humeral stumps longer than the ideal may prevent the fitting of the type of arm that provides the best functional results, because there is not enough space for the fitting of the automatic elbow mechanism.

Disarticulations at the elbow are still in disfavour; the extra leverage is of no advantage, and the prosthesis that can be fitted is not comparable in efficiency with that available for the ideal stump.

Amputation below the elbow—The ideal length continues to be seven inches. Owing to improved methods of fitting and suspension much shorter below-elbow stumps can now be fitted than was once found possible, and therefore the elbow joint should not be sacrificed without much consideration. Stumps longer than the ideal tend to develop circulatory defects, and the extra length is of no advantage.

For all arm stumps amputation by equal anterior and posterior flaps, giving a terminal transverse scar, provides the best results.

Disarticulation at the wrist—This operation has always been regarded with disfavour in past years because the limb provided was bulky and projected beyond the extremity of the natural hand. Recently, however, the prosthesis has been redesigned to avoid excessive length. Although the stump is bulky it is considered that this operation has a place in men (Perkins 1953) but not in women for cosmetic reasons.

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PREPARATION OF THE AMPUTEE AND STUMP FOR LIMB FITTING

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Successful rehabilitation of the amputee is dependent upon a number of factors, of which one of the most important is the mental and physical preparation of the patient for limb fitting and training. Without adequate preparation the limb fitters and training instructors will not achieve the greatest success. In this paper we have confined our attention, in the main, to the management of the patient and the stump in the interval between amputation and limb fitting.

THE LOWER EXTREMITY

Pre-operative preparation—Elderly subjects about to undergo amputation for peripheral vascular disease should be taught certain exercises before operation. These are: 1) basal expiratory breathing exercises and coughing to reduce the risk of post-operative atelectasis and pulmonary infection; 2) exercises to maintain the circulation in the surviving foot and leg; 3) static contractions of gluteus maximus on the affected side to counter the tendency to flexion of the stump from contraction of iliopsoas and from posture; 4) exercises to strengthen the trunk and assist in preparation for the use of crutches. It is not essential to teach the last mentioned exercises before operation, but it is easier to teach patients before they are incapacitated and it helps their morale to feel that a confident and understanding physiotherapist is preparing for their early rehabilitation even before the operation.

There is seldom opportunity to teach exercises before emergency amputations after injury. In the young and middle aged this is of little disadvantage, but in elderly and bronchitic subjects basal breathing, coughing and movement of the unaffected foot and leg should be started immediately after operation.

Care of the stump after operation. *Amputations above the knee*—On return to bed after operation the stump should be extended and no pillows or support should be placed beneath it at any time. A few days after operation compression bandaging can be begun, using but little terminal compression at first. Compression should be increased as it is found that the patient can tolerate it. The purpose of compression bandaging is to assist in the absorption of terminal oedema, not to shape the stump in any way; bandaged in this manner the patient finds the stump supported and more comfortable, and the bandage should be used when he is up on crutches. Firm terminal compression, however, should cease as soon as the terminal oedema has disappeared, because it is desirable that nothing should restrict activity and development of the muscles in the stump.

As soon as possible, while still confined to bed, the patient should be encouraged to begin redeveloping severed and other muscles acting on the stump. Active exercises for the redevelopment of the hip adductors are essential because subsequent limb control depends upon them, and should be carried out against the increasing manual resistance of a physiotherapist. Hip extensor exercises are necessary to counteract the much reduced opposition to iliopsoas, and again because the glutei are used to maintain extension at the knee joint of the artificial limb in walking.

As soon as the patient is up on crutches these stump muscle exercises are continued in the physiotherapy department, with the use of a canvas sling attached to a weight and pulley. An initial weight of five pounds may be increased up to fifteen pounds as the muscle strength develops. It is most important that hip flexion through an overacting iliopsoas be obviated before limb fitting is begun.

General massage to amputation stumps is undesirable because there is a risk of irritating severed nerve endings, but massage can be used with advantage over a restricted area when there is a risk that a scar will become adherent.

Amputations below the knee—It is necessary to ensure that no flexion develops at the knee joint and when the patient is returned to bed no support should be placed beneath the knee. Compression bandaging by the method described is desirable; a turn of the bandage is carried above the femoral condyles, leaving the knee exposed so that quadriceps exercises may be begun as soon as possible without removing the bandage. These exercises should be continued in the physiotherapy department with a suitable sling, pulley and weight system.

Preparation of the patient—Whenever possible rehabilitation should start as soon as the patient enters hospital. His morale, general physical and mental fitness, and confidence in his early resettlement in his home and suitable employment should be ensured by early contact with the social workers and by remedial exercises and occupational therapy. Sometimes, however, for various reasons there has been a long stay in hospital or a long period of immobilisation either before or after amputation. Such patients should not be subjected to the strain of limb fitting until they have undergone a period of remedial exercises for the

FIG. 1
Group exercises in the gymnasium.

general toning up of the muscles, for the mobilisation of stiff joints and the strengthening of muscles acting upon the stump. This is especially important in elderly persons, some of whom have failed to succeed in wearing their limbs through lack of such preparation. On the other hand, remarkable improvement takes place even in the very old after two weeks or so of general remedial exercises, carefully graduated, in that they acquire a feeling of physical well-being and mental alertness such as they had not experienced for many years, and are ready and anxious to undertake the training in limb wearing. The emphasis should be upon general remedial exercises because patients attending limb centres frequently exhibit the following conditions: flexion of the cervical spine and stiffness of the fingers through prolonged use of wheel chairs and crutches; weakness of the muscle of the back, abdomen and the remaining lower limb; and stiffness of all the joints, especially those of the lumbar spine.

The exercises should be carried out in groups, and if there are enough patients they may be segregated by age. Patients may sit upon mattresses laid in lines facing one another, or sit in wheel chairs. Medicine balls are passed or thrown from one patient to another and a spirit of competition and humour should be introduced (Fig. 1). For example, a competition between two lines of patients passing a medicine ball from one to another down the lines in such a way that spinal rotation is called for is particularly beneficial.

UPPER EXTREMITY

Care of the stump—In dealing with arm amputations it is usual to concentrate upon preparation of the stump and it is seldom necessary, in so far as the subsequent use of an artificial arm is concerned, to provide general remedial exercises as in the case of patients with amputations through the lower limb.

As with the lower extremity, compression bandaging should be used both for above-elbow and below-elbow stumps so long as terminal oedema remains. Mobilisation of the proximal joint in an arm stump is very important, particularly the shoulder joint in the case of the above-elbow stump. Unless a full range of movement is obtained the best results cannot be gained from the use of the artificial arm.

Preparation of the patient—Early reassurance and rehabilitation are even more important than with the lower extremity, because the psychological effect of the loss of an upper limb is far greater.

A patient who has had one arm amputated, having recovered from the mental and physical shock of the operation, is apt to resign himself to becoming a one-armed person. Unless properly briefed, he feels that his artificial arm, when supplied, will be of merely aesthetic value. This attitude develops during his stay in hospital after operation but it can be counteracted with ultimate advantage. Although there is a natural tendency among nurses and others to assist the patients in every possible way it is better to leave them to help themselves, provided they are supplied with the means for doing so.

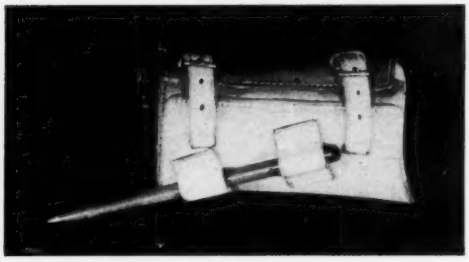

FIG. 2

Leather gauntlet to which a pencil or other appliance may be fitted. This is useful in the early weeks after an upper limb amputation.

These means are simple, such as bandaging a pencil at the extremity of the upper arm stump, and, for forearm cases, a spoon or fork with which they can feed themselves. A piece of india-rubber attached to a stick bandaged against the stump enables the patient to turn the pages of a book. A leather gauntlet (Fig. 2) is a simple accessory which can be used with above-elbow or below-elbow stumps. These gadgets enable the patients to become independent of others, which they all desire when they realise independence is possible. Thus encouraged, patients begin to realise that after all the stump is going to be of some use; they are, therefore, less likely to become " one-arm minded " and take more readily to the use of the artificial arm when supplied.

BEST TIME FOR LIMB FITTING

Lower extremity stumps—Lower extremity stumps fitted with a limb must tolerate a certain amount of friction and traction through unavoidable piston action, though with modern methods of fitting this has been greatly reduced. Fitting should not begin, therefore, until stability has been reached after operation; that is, the stump must be soundly healed, terminal oedema dispersed and the severed nerve endings sufficiently quiescent to permit firm handling of the stump. In an uncomplicated above-knee stump these conditions should be met in two months after operation, and in the case of a below-knee stump a little over a month should suffice.

Upper extremity stumps—Upper limb stumps are not called upon to bear weight or traction, and friction is minimal. This is fortunate because the sooner an arm stump is fitted with a limb the better the chance of the patient's making use of it before he has become entirely dependent upon the sound hand. An arm stump should, therefore, be fitted as soon as the

stump is healed and terminal oedema has become absorbed. Some stumps have been fitted as early as three weeks after operation.

TRAINING IN THE USE OF THE LIMB

It is impossible here to cover the whole field of limb training in detail, and therefore we will confine ourselves to enumerating the basic principles.

Lower extremity stumps fitted with articulated limbs. *Amputations above the knee*—Training should begin by promoting a sense of balance and power of control of the limb, and by measures to harden the tissues under the ischial tuberosity, upon which weight is borne. The natural inclination of most patients is to begin walking at once, but this must be curbed. The weight-bearing tissues are sensitive at first, and if much walking is begun too early a limping gait results, more time being spent on the good leg than on the artificial.

For the first day or so practice should comprise standing erect at one end of the walking rails with weight evenly distributed between the legs; then first one leg and then the other should be lifted from the ground as if " marking time." This exercise not only hardens the weight-bearing tissues but also develops a sense of balance and of stump muscle control of the artificial limb. Walking within the rails may then begin, short paces of equal length being taken. The artificial leg is flexed at the knee by the power of the stump, and as the patient moves forward the heel touches the ground, as if making a mark at rugby football, extension of the stump within the socket causing extension of the knee. The body weight is carried forwards on to the instep of the foot, by which time a pace of equal length will be taken with the natural leg. The hands should not be placed too far forward on the rails because this produces a tendency to lordosis; the head and shoulders should be held erect.

When balance and control have been acquired the patient proceeds to walk in the open room using two sticks of correct length. From this stage he progresses to certain specific exercises of the following nature: ascending and descending steps of slightly differing dimensions; learning to approach a chair, turn and sit down in the proper manner; while walking, to stop, stoop and pick up an object from the floor. Walking on a cambered surface, and stepping on and off a curb, are practised; and finally, before he walks out of doors, the patient should practise falling upon a mattress and should learn the correct technique for rising from the ground.

No one exercise should be continued for long in the early stages; with elderly patients effort reaction must be closely watched, frequent rest periods often being needed.

During walking exercises instructors will closely observe the gait, control and action of the artificial limb, and look for such defects as a shooting of the knee through lack of hip extensor action, for correct tracking of the limb without abduction or rotation, and for the rate of knee extension which may necessitate an alteration or adjustment of the knee-control brake, if used. Finally the stump should be examined regularly during exercises. A tendency to reddening of the skin at any one point indicates a need for adjustment of the socket. It is during the early walking stage that slight variation in contour of the stump takes place as the muscles develop, and appropriate adjustments to the socket should be carried out by the limb fitter before any further exercises are undertaken. Failure to have socket adjustments carried out directly the need arises may result in harm to the stump and may induce a bad gait.

Amputations below the knee—For these the same exercises are practised but the retention of the natural knee joint renders the training period much shorter, because balance and control are soon acquired. The instructor must first determine the manner in which weight is intended to be borne upon the limb by the prescribing medical officer; it may be either tibial, part tibial and part thigh bearing, or ischial bearing. Thigh and stump changes during exercises may alter the bearing area levels in the case of the two latter. It is equally important that abnormal pressure marks upon the stump be noted and the socket of the limb adjusted when necessary.

The duration of training varies much according to age and physical condition of the patient, but it is usually found that for a below-knee amputation ten days will be enough; for an above-knee amputation fourteen days will be required and for amputations of both legs four weeks or more.

Upper extremity stumps—Training in the use of an artificial arm is provided in the arm training schools attached to certain limb-fitting centres. Training is entirely of a functional nature and no attempt is made to teach a trade, such instruction being provided later in the Ministry of Labour Vocational Training Schools if required.

The purpose of training is to instruct the patient in what can be achieved with an artificial arm and to convince him that it is not intended to be a mere " sleeve filler."

At first the patient practises putting on and taking off the arm and how to adjust the appendages. He next learns how to remove the artificial hand and fit in various appliances. In the case of an above-elbow amputation instruction is given in flexing the elbow by rounding

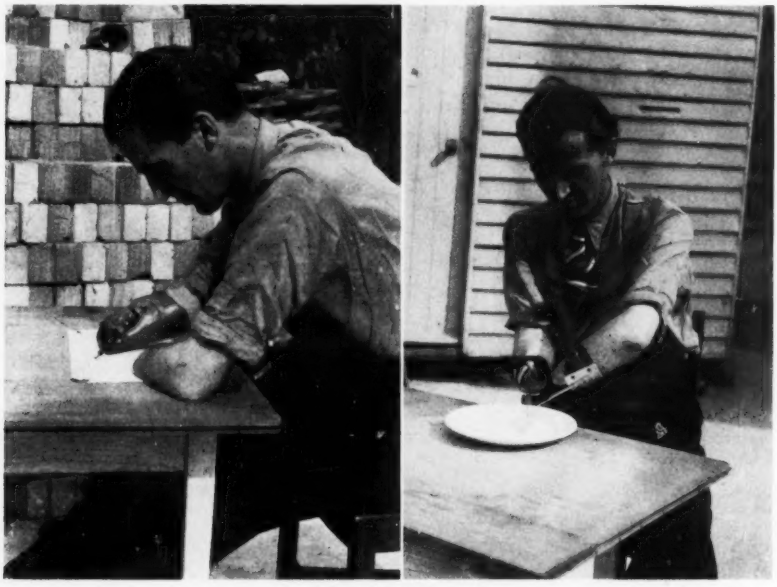

FIG. 3

A patient with double below-elbow amputations practising writing and feeding.

the shoulders and locking the elbow joint in the various degrees of flexion provided, by movement of the shoulder on the amputated side. The uses to which the artificial hand can be put for writing, feeding, and carrying articles are demonstrated and practised.

The patient will then pass on to trying out appliances, a large range of which are held in every training school, over 120 types being available. Carpentry is practised in every school, not as a vocation, but rather because the many operations involved and different tools used provide an excellent opportunity for practising with the various appliances.

Patients practise turning taps and switches such as will be used in their homes. Domestic appliances are tried out, especially by women patients, who are also enabled to use appliances for needlework. Desk and draughtsmen's appliances are available and typing is practised. Children obtain much interest and valuable practice by making wooden toys.

By the end of the course, which may be of ten to fourteen days for the single amputee, or of three or four weeks when both arms have been lost, the patient has acquired confidence

and efficiency in the use of the prosthesis; he will have selected the appliances most suitable to him for his future occupation, if this has been decided, and if not he will be ready to begin vocational training for which suitable appliances are provided when the nature of such is known.

It has been proved that with very few exceptions the functional and vocational efficiency of those who have passed through an arm training school is much greater than of those who have for various reasons refused to accept training, and therefore all should be prevailed upon to accept it in their own interests.

It has been shown that arm amputees make the best instructors in arm training and must be chosen not only for their efficiency in the use of their arms but also for their personality and ability to instil enthusiasm. If the one chosen has been a handicraftsman or technician, so much the better.

SUMMARY

One of the most important factors in the rehabilitation of the amputee is the preparation of the patient and stump for limb fitting and training. The different procedures for the upper and lower extremities are described. Emphasis is laid on the importance of early reassurance and rehabilitation whenever possible. Patients unavoidably immobilised for long periods require general physical reconditioning before limb fitting and training can be undertaken. Special care is needed to avoid the upper limb amputee's becoming dependent on the surviving hand and using the artificial limb only for its cosmetic effect.

KRUKENBERG-PUTTI AMPUTATION-PLASTY

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We owe cineplasty of amputation stumps to Vanghetti, who was first to publish in 1899 the various systems such as clubs, loops and so forth. It was greatly experimented with during and soon after the first world war. The initial enthusiasm diminished gradually because cineplasties were badly tolerated (frequent eczemas, ulcerations, etc.) and because of the prosthetic difficulties. In spite of the attractiveness of the theoretical conception, cineplasties have practically been abandoned. One only has survived: the forcipisation of forearm amputation stumps. The name was given by Vanghetti himself. The realisation is due to Krukenberg and Putti. Krukenberg thought of using directly the forearm stump by changing it into radial and ulnar pincers by complete separation of the two forearm bones. The two antibrachial fingers thus obtained can open and close in pronation-supination movements. Putti greatly reduced the length of the forearm " fingers " by separating the two bones for not more than five to seven centimetres. Krukenberg's technique, with the two long " fingers," makes direct prehension possible without the need of prosthetic integration. Nevertheless the stump is unsightly, and prehension is much less powerful than with Putti's technique because of the great damage caused to the muscle mass during the preparation of the two long " fingers." With Krukenberg's technique plastic reshaping of the skin is often necessary to cover the interdigital space well. Cutaneous sensibility is excellent with both methods.

My own considerable experience during the second world war enabled me to observe the great advantages and the superiority of Putti's technique over Krukenberg's. After having experimented with forcipisation of different lengths from four to seven centimetres, I am convinced that the best length of the two antibrachial " fingers " is six to six and a half centimetres (Figs. 1 to 3). The active spread with such a length is wide, and sufficient to enable patients to grasp directly, while the greatest strength of prehension is maintained. When the antibrachial " fingers " are only four centimetres long the strength may be greater but the spread is limited and therefore the possibility of direct use is reduced. With " fingers " longer than seven centimetres the opposite happens.

Indications—This method is especially advisable with bilateral amputations of the forearm and in any case when the subject is also blind. The advantage of two " fingers " with perfect cutaneous sensibility helps and improves considerably with reading braille and writing. This operation is likewise justified in forearm stumps with radio-ulnar synostosis, and consequent loss of pronation-supination movement. It is also logically indicated in all those cases in which the patient wishes or needs direct prehension with the stump and wants a safer and more precise movement as well as a better adjustment of the rotation prosthesis and of the different working devices that can be fitted to it.

The prosthesis—With forcipisation the ordinary rotation prosthesis is an excellent help, but the grasping cuff of the stump needs a slight modification. It has to be changed into a double cuff to fit and to cover the two antibrachial fingers; with their supination and pronation motion they control the opening and the closing of the two fingers of the prosthesis. With our prosthesis only the thumb moves: thus the transmission mechanism of the movement is simplified and the rotation movement becomes prehension. The photographs (Figs. 4 to 8) show better than any description the exact construction and working characteristics.

Technique of operation—A U-shaped cutaneous terminal incision is made, with its palmar limb lateral to the median line of the forearm and the dorsal limb medial to this line. After the two cutaneous flaps have been raised, the two forearm bones are separated, and then the

FIG. 1

FIG. 2

FIG. 3

Figure 1—Amputation stump before forcipisation. Figure 2—After Krukenberg-Putti amputation-plasty. " Fingers " closed. Figure 3—" Fingers " open.

FIG. 4

FIG. 5

FIG. 6

Figure 4—The prosthesis. Figure 5—The prosthesis applied, showing the thumb closed. Figure 6—The thumb opened.

musculo-tendinous mass is isolated and spread, and the interosseous membrane is divided, with pronator quadratus as well if the amputation is low. When the spread and the right digital length have been obtained the excessive muscle mass is removed so that the two cutaneous finger flaps can be sutured without tension. The muscle mass can be excised freely except for the pronator teres, palmaris longus and flexor communis digitorum. The last two must be included in the radial finger. In the case of a stump with radio-ulnar synostosis, especially frequent after disarticulation at the wrist, the bony mass must be freely removed extraperiosteally.

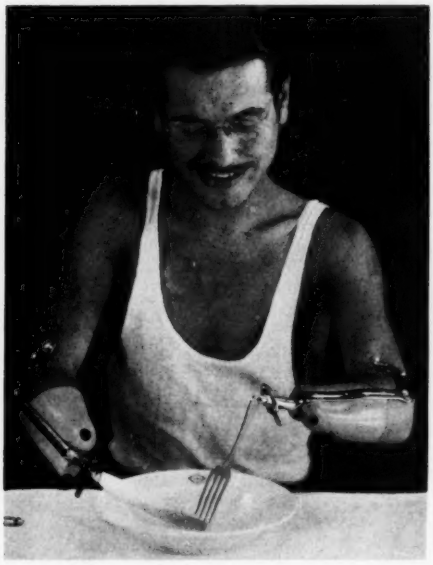

FIG. 7

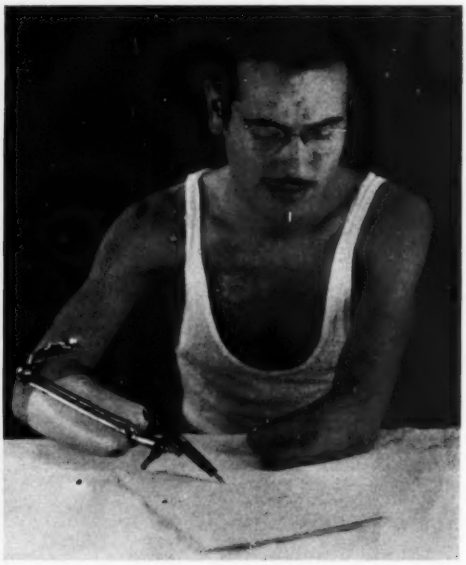

FIG. 8

A patient with both hands amputated demonstrating the use of implements fitted to the Krukenberg-Putti stumps.

The stump is kept as long as possible. The greatest prehension strength is obtained in forcipisation of the lowest third and middle third. That of the uppermost third is the least efficient. The Krukenberg-Putti forcipisation is really a very good operation which should be used much more than it is nowadays.

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THE PROSTHETIC MANAGEMENT OF CONGENITAL DEFORMITIES OF THE EXTREMITIES

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Congenital deformities of the extremities may come within the limb fitter's sphere after amputation or when, without amputation, there is sufficient shortening or deficiency to allow the fitting of an artificial limb to the deformed limb. The classification of these cases is difficult because they present wide variations in anatomy, but certain broad groups emerge in relation to prosthetic management. The material for this paper was gathered from a series of 166 cases with a follow-up of up to eight years, together with many others treated by the Limb Service both at Roehampton and in the provinces. The numbers of each type of case are shown in parenthesis in each section, but they are not to be taken as indicating the incidence of these conditions, because the series is composed of highly selected cases.

CLASSIFICATION

LOWER LIMB DEFORMITIES

Deformities primarily affecting the foot (two cases)—These deformities are not common. In appearance they may resemble a surgical partial foot amputation. Rudimentary toe buds may be present. There may be some shortening of the limb as a whole, and a degree of equino-varus has been seen in association with the foot deformity, as after surgical amputations at this level. One or more digital rays may be absent (Fig. 1).

FIG. 1

Congenital deformity of foot resembling Chopart's amputation. Note equino-varus and toe bud. (Mr Leon Gillis's case.)

Deformities primarily affecting the leg (twenty-seven cases)—The common deformity in this region is absence of the fibula. There is usually marked shortening, some of which may be due to associated shortening of the femur. The hip and knee are usually sound, but they may show flexion deformity, and genu valgum is not uncommon. Half the pelvis, and the long bones on the affected side, are sometimes underdeveloped. The ankle is usually unstable, with varying degrees of equino-varus. The tibia often shows deformity which may be anything from a slight bowing, usually forwards, to complete pseudarthrosis. The foot may be almost normal or it may be deformed. Commonly one or more digital rays are absent, there may be syndactylism of two or more toes, and the tarsus may be deformed and incomplete. A skin dimple can usually be found at the front of the leg, often at the junction of the middle and lowest thirds, which is the common site of bowing of the tibia.

Occasionally it is the tibia that is absent. Although the fibula may hypertrophy considerably, the limb is unsatisfactory. The ankle is grossly deformed and unstable, and perhaps the knee likewise, and weight bearing cannot be tolerated (Figs. 2 and 3). It is usually advisable to amputate the limb in these cases. The skin dimple is usually present.

Deformities primarily affecting the thigh (nineteen cases)—These deformities are also relatively common. The femur is shortened and there is often a severe flexion deformity of the hip and knee, so that the thigh is held much in the position seen in quadrupeds. The shaft of the femur

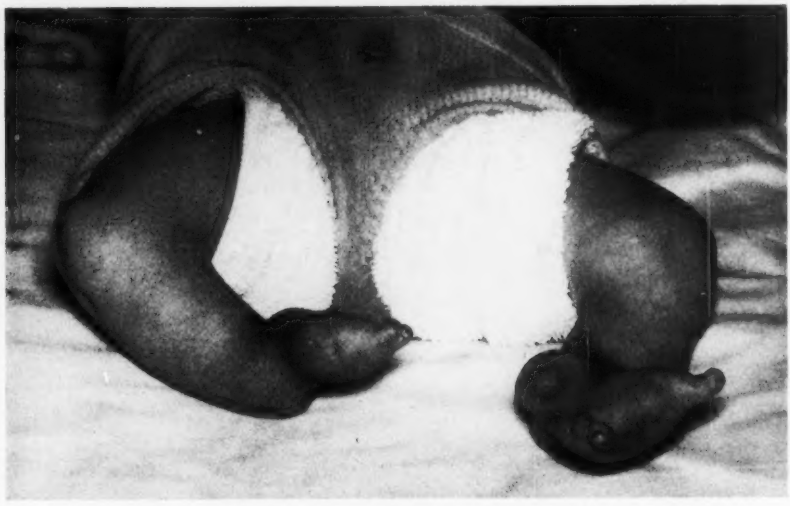

FIG. 2

Absence of both tibiae. This patient was treated by disarticulation at the knees. (Mr J. M. Turner's case.)

may be deficient in various ways (Fig. 4). It may be represented by a relatively normal lower end, tapering away to a point a few inches proximally. The head and neck may be absent or underdeveloped, and there may be severe coxa vara. There is sometimes a pseudarthrosis of the femur. The hip may have good function, or it may be rudimentary and represented by a shallow or absent acetabulum with the attenuated upper end of the femur lying more or less in its proximity. The skin dimple can usually be found.

The knee is often sound, but flexion deformity is common. The leg and foot are usually normal. These limbs are usually surprisingly strong, and, even in girls, may be strikingly hirsute in comparison with the other limbs.

Congenital amputation stumps—A congenital deformity having the appearance of a surgical amputation stump is rare in the lower limb, but common in the upper. When it occurs in the lower limb it usually takes the form of a below-knee stump which may be very short. The epiphysis may be present and the anatomy of the hip, thigh and knee is usually fairly normal, but congenital dislocation of the hip in association with a congenital through-knee "amputation" has been seen. Toe buds are common. This type of deformity, in the lower limb, has not been seen as a solitary defect (Fig. 5).

FIG. 3

FIG. 3

Absence of tibia. This patient had been treated by a Syme's type of amputation. He is wearing a conventional below-knee prosthesis, but it is doubtful how long the stump will tolerate weight bearing. (Mr J. I. P. James's case.)

Multiple and bizarre deformities (thirty cases)—The deformities described above may exist singly or in combination. They may be confined to one limb. There may be a concomitant deformity of the upper limb, in which case it is usually, but not necessarily, the same side

FIG. 4

Femoral deformity of rather unusual type which was nevertheless evidently congenital. The deficiency seems primarily to affect the shaft. A skin dimple was present.

FIG. 5

Multiple congenital deformities including amputation type deformities of both legs and left forearm. Note the characteristic intelligent and attractive facies.

that is affected. Both legs may be deformed, in which case the deformities are seldom symmetrical (Fig. 6). One patient has been seen with total absence of both lower limbs, the asymmetry in this case being represented by slightly greater development of one side of the pelvis and greater bulk of the overlying soft tissues. Two children have "amputation-stump" deformities of all four limbs.

"Constriction band" deformities (four cases)—Some limbs show appearances which suggest that they were caused by constriction. A constriction ring is present, the limb distal to the ring being atrophic to a varying extent (Fig. 7). The site of the constriction ring is not constant. There may be loss of the extremities of the limb; thus the toes may be absent or represented by buds, or there may be greater deficiencies up to an amputation-stump deformity. The circulation of the distal part of the limb may be precarious. It seems possible that the mechanism producing constriction band deformities also produces the amputation-stump

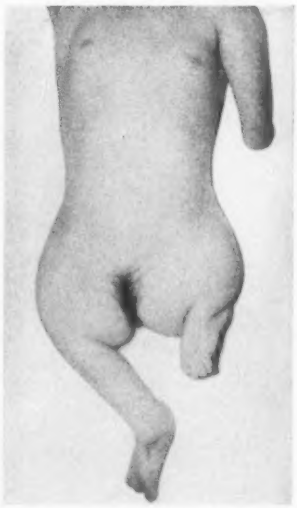

Fig. 6

FIG. 6

Multiple congenital deformities. Right leg deformity is primarily femoral. Left leg is represented by a foot placed close to the buttock. Left arm shows "through elbow" amputation stump. Note skin dimple on right shin. Operative stabilisation of the right ankle was performed before limb fitting. (Mr E. W. Somerville's case.)

FIG. 7

Deformities of the lower limbs, with tubing applied to the sulci to demonstrate the possibility of the umbilical cord's having produced the constrictions. (Mr Leon Gillis's reconstruction.)

deformity if the constriction is sufficiently severe (Fig. 8). Absence or deficiency of the long bones has not been seen in association with constriction band deformities in this series.

Amputation necessitated by spina bifida (seven cases)—Although these are not cases of deformities of the extremities, they arise out of a congenital deformity and are conveniently included in this paper. When amputation is resorted to in these cases it is commonly on account of trophic ulceration of the feet. These patients present one of the most difficult problems to the limb fitter. The stumps often lack sensibility completely or in part, and the incontinence that is so often present adds to the difficulties of providing a prosthesis that will not cause chafing and further ulceration of the stumps. When the skin overlying the ischial tuberosities is also anaesthetic the problem may be beyond solution. Because of these difficulties in limb fitting, amputation should be undertaken only as a last resort, and the prognosis in respect of function with artificial limbs should be guarded (Figs. 9 and 10).

Fig. 8

FIG. 8

Severe constriction band deformities of both lower limbs. Relief of constriction by plastic surgery was required because of circulatory deficiency before a prosthesis could be tolerated on the left side. (Mr R. J. V. Battle's case.)

FIG. 9

FIG. 10

Figure 9—Congenital absence of sacrum and lower lumbar vertebrae. There were trophic lesions of lower limbs. Treated by amputation of the right leg below the knee and disarticulation at the left knee. Patient is now walking on more or less conventional prostheses. (Mr Vincent Snell's case.) Figure 10—Same patient, showing preliminary pylons. Note extreme development of shoulder girdle and arms. This boy ultimately mastered articulated legs.

FIG. 11

FIG. 12

Figure 11—Through-elbow amputation type deformity. Note hand bud. (Mr E. E. Harris's case.) Figure 12—Severe bilateral deformities of arms. Fusion of elbow joints and shortening. Note absence of opposition of thumb and fingers. Skin dimple is seen on the right arm. (Sir Arthur Porritt's case.)

UPPER LIMB DEFORMITIES

Congenital " amputation stumps " (twenty-four cases)—Congenital absence of the distal part of an upper limb is not uncommon. Since the deformity resembles that resulting from surgical amputation, most of the patients are sent to a limb-fitting centre. This may account for the preponderance of this type of deformity among our cases. Thus out of twenty-eight new patients with congenital deformities referred to Roehampton in the past six months, fifteen had this type of arm deformity. In order of frequency the common sites of congenital amputation are: below elbow, through wrist, carpal or metacarpal, through elbow, above elbow, shoulder (Fig. 11). Most of these cases are treated by routine methods and are therefore not included in the present series.

Deformities affecting the hand (fifteen cases)—These usually take the form of syndactyly, microdactyly, etc., and seldom come before the limb fitter.

Multiple and bizarre deformities (sixteen cases)—The common feature of most other arm deformities is fusion of the elbow joint with varying degrees of shortening. The hand may be almost normal or may show deficiencies in digital rays, especially of the thumb. There may be only one digit, or there may be an aberrant digit sticking out at a grotesque angle. Syndactyly is common. The skin dimple can often be detected. These deformities are incapacitating, especially as they are often bilateral. Fortunately they are uncommon (Fig. 12). Complete absence of both upper limbs has been seen.

GENERAL MANAGEMENT

Children exhibiting these deformities are nearly always of high intelligence and often they are strikingly handsome. The sexes seem to be equally affected, and all social grades are equally at risk. Little evidence in favour of a hereditary trend has been found. If confirmed, this observation puts these deformities in sharp contrast to such conditions as syndactyly and polydactyly, in which a hereditary influence is accepted (Barsky 1951, Bagg 1929) and a further study of this important aspect of the problem is being made.

Psychological adjustment to these deformities is usually good, especially when a reasonably good aesthetic and functional result is obtained by limb fitting. A few children have shown aggressive or exhibitionist traits, and one child developed a facial tic. Such reactions usually resolve when the child goes to school. Unless deformities are grotesque or severely disabling the children should go to a normal school, where their high intelligence stands them in good stead.

Abnormal psychological reactions in the parents of deformed children are more common. There have been instances of suicide of one or both parents after the birth of a severely deformed child. Marriages have broken down through one parent's implying that the deformities in the child were the result of bad stock on the other parent's side or through allegation of cruelty during the pregnancy, or from morbid obsessions of guilt. Some parents have deserted a deformed child or simply refused to have anything to do with it, necessitating its being cared for in a nursery or a school for the disabled. In most cases, however, the parents accept the child and their responsibilities to it and manage it well with the right mixture of sympathy and firmness. They are encouraged to make little of the deformity and to treat the child as normal.

PROSTHETIC MANAGEMENT

LOWER LIMB

Every patient with a congenital deformity presents an individual problem. Detailed clinical and radiological examination is necessary to assess the capabilities of the deformed limb, the range of movement of the joints and the capacity for weight bearing. In general, if there is enough shortening to allow of the fitting of at least an artificial foot, most of these patients can be fitted with an extension prosthesis without surgical intervention, and in many

cases this will give the best functional result. In some cases operation to correct flexion or other deformity may have to be considered before limb fitting is undertaken. In others an amputation may be indicated.

Limb fitting for the lower limb is begun as early as possible, ideally when the child begins to make efforts to stand. At this stage, when the limbs have not been subjected to weight bearing, the deformities are probably not in their final state. It may seem politic to amputate, for example, a foot in equino-valgus with absence of the fibula. But an extension prosthesis can usually be fitted, involving nothing that is irrevocable, and amputation can be resorted to later if the functional or aesthetic result is unsatisfactory. It is surprising how many parents think that the deformed leg will grow to be normal in time if it is left to itself, and no amount of explanation will disillusion them. If the leg is amputated in infancy they may never accept that it was done for the best, and may continue to believe that all would have been well had the limb been left alone. A similar reaction has been seen in the children themselves. One child seen at the age of sixteen years had had below-knee amputations of both legs in infancy for deformities. Prostheses had been fitted but she had not done well with them. She was sullen and unco-operative, and it transpired that she had conceived a hatred for her mother for bringing her into the world with deformities, and for her father for agreeing to the amputations, for she thought that the limbs would have come right in time.

When contemplating amputation, therefore, the surgeon should satisfy himself that the operation will help the patient functionally or psychologically and should resist the natural temptation to remove freak anatomical structures and leave a stump of serviceable appearance. In young children amputation should be resorted to only when there are clear indications that the child will gain in function. Very rarely psychological reactions may make operation necessary, but these can usually be overcome by suitably reassuring the child and, more particularly, the parents.

Nevertheless, a conservative attitude can be maintained too long, as the following case illustrates. A girl had been in our care wearing an extension limb for congenital absence of the fibula since the age of eight. The functional result was excellent, but aesthetically it left much to be desired. Through our failure to recognise that she was a precocious child she became self-conscious of her appearance, refusing to wear anything but slacks, and became unruly and unmanageable. A Syme's amputation was ultimately agreed to at the age of fourteen; the aesthetic result was good, and psychologically the child was restored to normal. This child would have had a happier childhood if her parents' request for amputation had been met earlier.

It should not be forgotten that a girl reaching maturity is at a serious disadvantage in her prospects of marriage if she has a freakish deformity and, although an amputation is also a handicap in this respect, a relatively normal looking stump may be more acceptable to the prospective husband than a deformity which is more or less bizarre. It is probable that this is in the minds of some of the girls who seek amputation for cosmetic reasons as they grow up.

It follows that each case must be treated on its merits and, in borderline cases, the greatest care must be taken in balancing the functional and psychological requirements. Nevertheless, especially in the younger patients, it is felt that nothing can be lost by an attempt to fit an extension prosthesis in the first instance, resort being made to amputation only if the results fall short of requirements. Whenever possible surgery should be deferred until the child is old enough to share in the decision.

The extension prosthesis is constructed as follows. A boot, into which the natural foot is fitted, is made to a cast of the foot in a position of equinus and fixed on a platform. The greater the equinus the less obtrusive is the prosthesis, but care should be taken not to force the position to the extent that the heel slides off the platform. Some assistance can be obtained by fitting the toes in slight dorsiflexion. Below the platform, as much as is possible of a conventional prosthesis is applied by means of side steels in much the same way as in the

O'Connor appliance. The side steels may be extended upwards to carry a thigh corset which can afford ischial bearing if required. Knee joints can be fitted to the side steels and such devices as T-straps and patella straps applied. The whole appliance is made and set up to a cast of the deformed leg. For young children the lower part of the appliance is made from wood, with a fixed ankle and a felt forefoot. For adolescents and adults a metal base may be used, and in a few cases it may be possible to enclose the deformed foot more or less completely within the shell of a metal shin with excellent aesthetic effect. One such patient was enabled to achieve her ambition of singing on the concert platform, which she had been too sensitive to do before.

Deformities primarily affecting the foot—These limbs can usually be fitted with one of the conventional prostheses for Chopart's amputation, with relatively minor modifications. When there is shortening of the leg as a whole it may be necessary to make a modified platform limb. This gives good function but is unsightly because of the bulk at the ankle.

FIG. 13

Congenital absence of fibula. Drawing prepared by superimposing tracing of radiograph on sketch of prosthesis. The boy came third in his school high jump in open competition with normal children.

FIG. 14

Old-standing tuberculous hip with premature epiphysial arrest and backward subluxation of the knee. The hip was ankylosed. Fitted with corset-top caliper with free knee joints mounted on platform prosthesis. Cross knee strap and calf band tended to correct knee deformity.

Deformities primarily affecting the leg—These deformities are usually associated with sufficient shortening to allow of the fitting of an extension prosthesis. The capacity of the limb for weight bearing must be assessed; if it is in doubt an ischial bearing corset should be fitted, although it is usually possible to retain knee function by fitting joints to the steels (Fig. 13). The varus deformity that is commonly present at the ankle can be controlled by a T-strap. Tibial bowing, flexion contractures at the knee and hip, and genu valgum frequently improve under the stimulus of weight bearing, and may disappear entirely. When the knee and hip are sound the boot does not need to be extended beyond the tibial condyles, which can be used, by means of a blocked leather boot, to accept some of the weight load if this is desirable. Genu valgum can often be helped in young children by a wedge inserted between the ankle and the foot of the prosthesis.

The functional result with this type of deformity is uniformly good after satisfactory fitting with a prosthesis. Many patients can even run without a limp. One boy was placed third in his school high jump in competition with normal boys. The aesthetic result is less

satisfactory, and amputation at the ankle may be required in girls at a later stage for this reason alone. Patients with a tibial pseudarthrosis which fails to unite probably require amputation through the pseudarthrosis to get satisfactory function.

Patients with shortening from arrest of growth after poliomyelitis, tuberculous disease or other causes can be fitted with a similar extension prosthesis. When control of the hip is weak it is possible to fit a rigid hip joint and pelvic band to the top of the outer side steel. There are fifteen such cases in this series (Fig. 14).

Some cases of leg deformity have been referred to the limb centre after amputation. This usually takes the form of a modified Syme's amputation, the foot being removed at the ankle joint. The resulting stump is usually satisfactory and can tolerate end bearing. The end of the stump is not so bulbous as is a true Syme's stump. Patients with this type of amputation are usually fitted with the metal enclosed type of Syme's appliance, a fixed ankle and felt foot being used while the child is small. The functional results are comparable with those of an extension prosthesis, but if the fibula is absent there may be difficulty in preventing

FIG. 15

Congenital atresia of upper parts of femur. Diagram showing prosthetic fitment. Note ischial bearing and free swinging artificial knee joint. The pelvic band was necessary in this case because of lateral instability.

FIG. 16

Child aged two and a half in whom the right femur is absent, showing the normal existence open to these patients. Fitted with extension prosthesis of the type shown in Figure 15, except that a pelvic band was not required. (The late Mr Eric Lloyd's case.)

the prosthesis from rotating on the stump. It must be admitted that the aesthetic result is better and, indeed, may be perfect. Occasional difficulty has been experienced with young children who have been subjected to amputation in that the memory of painful experience remains and they are frightened and unco-operative. This can usually be overcome by the removal, by those in attendance, of the white coat and by suitable distractions in the way of playthings and sweets. If the child will not permit a cast to be taken at the first visit a second attempt a few weeks later is usually successful.

When the tibia is absent it is seldom possible to conserve a functional knee joint, and a disarticulation at the knee will probably be required, followed by the fitting of a conventional prosthesis.

Deformities primarily affecting the thigh—These cases provide a more difficult prosthetic problem. The flexion deformities of hip and knee are such that the knee is usually more or less at the same level as the hip and lying anterior to it, so that the axis of the leg is anterior to that of the bodily centre of gravity. If a platform prosthesis is fitted in the axis of the leg it is unstable and tiring to manage, and a free swinging artificial knee cannot be controlled.

If the whole weight is carried by the foot on the platform there is a strong tendency to " jack-knifing " at the hip and knee. The movement of flexing and extending the shank on the trunk is a complex one commonly taking place partly at the hip but mostly at the knee, and at the pseudarthrosis if present. If it is necessary to use an artificial hip joint its best position can be determined only by trial and error.

It follows that the extension prosthesis for deformities of this type must usually afford ischial bearing. The side steels should be allowed to incline slightly backwards from above downwards so that, at the level of the platform, they are in the plane of the axis of the centre of gravity. The natural heel is then usually at about the same level as the normal knee. Knee joints can be fitted to the steels at this level, the boot on its platform being attached to the upper section of the steels (Fig. 15). Function with this type of prosthesis is usually quite good, and is comparable with that obtainable by a patient with disarticulation at the knee. Aesthetically the anterior position of the knee produces a bulge which may be more or less

FIG. 17

FIG. 17

Right leg is similar to that shown in Figure 15, except that the femur is more nearly complete. Illustrates the difficulty of concealing knee and foot. The left leg has apparently been represented by some rudimentary structure of the type shown in Figure 18, but this unfortunately was amputated in infancy. A tilting table prosthesis has been fitted. (Mr F. G. St Clair Strange's case.)

FIG. 18

Congenital deformities of both lower limbs showing prosthetic fitments. The right prosthesis is an extension limb. On the left a more or less conventional above-knee prosthesis was possible. This child goes to a normal school. (Mr S. L. Higgs's case.)

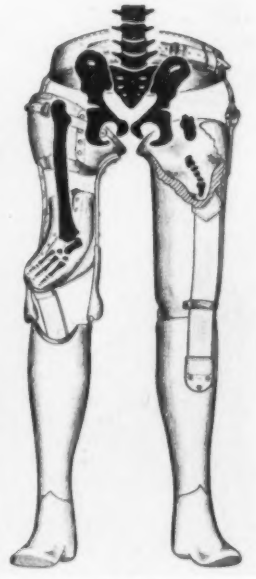

FIG. 18

conspicuous according to the length of the femur. In a sitting position the toes tend to project forwards and show through the trouser leg or below the skirt. This can be minimised by setting the artificial knee joints as low as possible (Fig. 16).

In some cases the prosthetic problem has been simplified by surgical correction of the deformities of the hip and knee flexion, with arthrodesis of the knee in extension. This may give an excellent limb in good alignment, with robust function on a platform prosthesis.

Sometimes a Syme's amputation, either alone or in association with a corrective operation, has been used. The stump can then be fitted into a conventional thigh prosthesis if the socket is modified appropriately, but care must be taken that the socket is aligned in the container in such a way that the axis of the prosthesis is in the plane of the axis of the centre of gravity rather than in the line of the tibia. The aesthetic result of this procedure is good, but it is doubtful if the functional result is ever so robust as that obtained with the extension prosthesis.

Van Nes (1950) described another method of treating these cases. Arthrodesis of the

knee is performed and a femoral osteotomy is done. The distal fragment is rotated through 180 degrees and retained in this position while the osteotomy unites. This brings the heel round to the front. The foot is fitted into a specially fitted socket within an otherwise conventional below-knee limb prosthesis. The patient's ankle then acts as a knee to control the movements of the artificial shin. Aesthetically and functionally the possibilities of this technique seem good if the full 180 degrees of rotation can be ensured, and if there is no residual flexion deformity of the hip. I have seen only one patient so treated. In this case the rotation was a few degrees short of 180 degrees, and after a subsequent accident in which the femur was refractured union occurred with still more loss of rotation, resulting in difficulties in the alignment and " tracking " of the prosthesis. There was a slight residual flexion deformity of the hip, and the boy never walked with great confidence and could not part with his stick. It is emphasised that the relative failure of this case was due to alignment

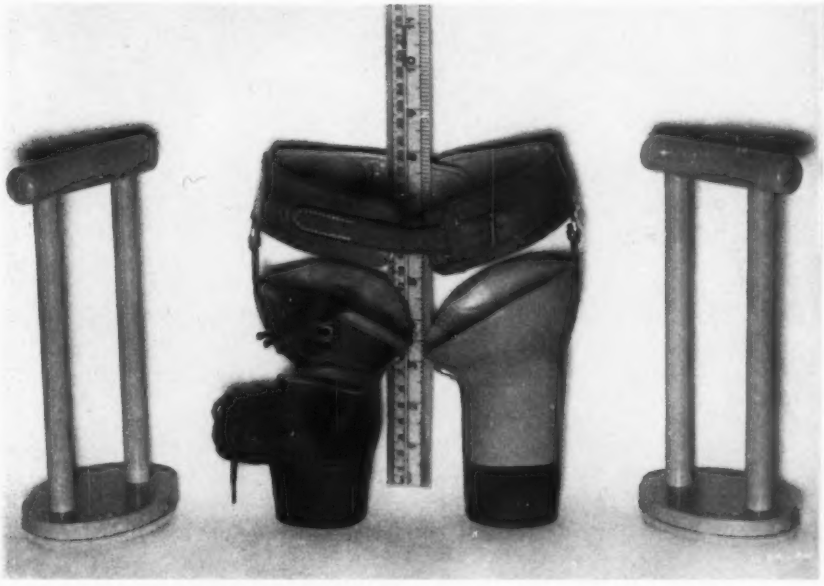

FIG. 19

The first set of prostheses supplied at the age of two years to the patient shown in Figure 18. The type of walking stick with flat base illustrated has proved of value for young children.

problems and does not necessarily imply that the principle is unsound. It was interesting in this case to note that the calf muscles took over the function of the quadriceps in the rhythm of gait immediately and without extensive re-education. Presumably the reflex originates in the plantar sensory nerve endings (Whillis 1953).

Congenital amputation stumps—These can be fitted with conventional limbs and present no special difficulties unless there are complicating factors such as congenital dislocation at the hip. The latter will probably necessitate the provision of an ischial bearing limb and, if a prosthetic hip joint should be required, the correct position for it may be difficult to determine and must be decided by trial and error.

Multiple and bizarre deformities—These produce problems of great complexity and each case must be taken on its merits. When both lower limbs are short it is often possible to begin prosthetic work on the shorter of the two, the longer limb being fitted without extension, if necessary with a surgical boot, and possibly with a caliper if required for stability. When

mastery of this apparatus is achieved, progression is made by fitting an appropriate extension prosthesis to the longer limb to bring the limb into proportion with the general bodily physique, the prostheses for the shorter limb being lengthened correspondingly (Figs. 17 to 19).

For example, the patients with one limb represented by a foot located close to the buttock, and the other limb by a deformity of the thigh, have undergone the following programme. First the foot on the short side was fitted on a specially made ischial bearing socket within an otherwise conventional thigh pylon. In one case in which the small foot had, unhappily, been amputated, it was necessary to use a tilting table pylon. The length of the pylon was adjusted to permit of weight bearing on the other limb with no prosthetic equipment apart from a surgical boot and ischial bearing caliper if required. When stability and control had been achieved the pylon was replaced by a fully articulated conventional prosthesis, and an extension prosthesis was fitted to the other limb deformity. The raising to full stature was done in several stages. The results in these cases have been very gratifying. Some patients are even able to go to normal schools.

Constriction band deformities—These cases are treated on similar general principles. Thus, a patient with ring constrictions at both ankles was fitted with a simple extension prosthesis on the shorter side and was beginning to walk, but ulceration from circulatory deterioration made it necessary to have a " Z-plasty " done to improve the blood supply. It is probable that this patient will require amputation eventually.

Spina bifida with amputation—Amputation stumps in association with spina bifida are almost always partly anaesthetic, and it is necessary to relieve these areas of weight bearing and friction. The general principles of limb fitting are applicable. The below-knee stump must be protected by full ischial bearing when sensibility in that area is adequate, and a loosely fitting felt-lined slip socket suspended to the stump by elastics protects the anaesthetic stump. When there is incontinence the prosthesis must be protected against the corrosive effects of urine. The leather-work is treated by coating with leather lacquer. Various plastic coatings have been tried, but it is difficult to obtain satisfactory bonding and the plastic skin has tended to peel or flake. Recent work suggests that silicones may be of value for this purpose. Polythene thigh corsets have been used with some success. The steels can usually be protected adequately by heavy plating. Duralumin is very susceptible to corrosion. A good cellulose paint will protect the metal provided it remains unscratched. Anodising is also effective so long as the skin so formed remains intact, but this method is expensive and scratches will not readily be seen until corrosion has set in. Stainless steel is also a possibility but it is difficult to work.

UPPER LIMBS

It is not our practice to begin limb fitting at such an early age in upper limb cases as in lower. The instinct to walk is practically irrepressible, and use can be made of this in fitting a prosthesis to the lower limb at about the age when the child could normally be expected to start walking. In the case of the upper extremity, however, the deformed arm or stump is used freely and is usually sufficiently dexterous to meet the simple needs of the very young child, who is not self-conscious of the deformity. Nevertheless we regard it as important to have the child fitted with the prosthesis and accustomed to its use by the time he goes to school. At this stage he is plunged into a new environment, and to reduce his inevitable sensitivity to comment by his fellows, he should look as normal as is possible. Apart from this we have no hard and fast rules but, by keeping these patients under observation, begin prosthetic work when the child's intelligence has developed sufficiently to co-operate well. The youngest child that we have fitted with a functional arm prosthesis was two and a half. We have known instances in which premature limb fitting has caused the child to form a revulsion from the prosthesis and to persist in refusing to wear it through the years.

The usual procedure is to fit first a simple arm of largely aesthetic value, and to progress to a more functional arm as intelligence develops.

FIG. 20

Hand represented by single powerful digit. Palm case with artificial thumb was provided to give opposition, but the appliance was of little practical value.

Congenital amputation stumps—These can be fitted with the conventional prosthesis appropriate to the length of stump, and no special difficulties arise.

FIG. 21

Congenital absence of fingers. This sort of hand is infinitely more useful in its natural state. Even a purely "dress" prosthesis will be bulky and of poor aesthetic appeal. (Professor T. Pomfret Kilner's case.)

Deformities affecting the hand—These seldom come within the province of the limb fitter unless the hand lacks the power of grasp. In these cases it may be possible to fit a palm case carrying an opposition plate like that used for a partly mutilated hand. In this way pincer function can be provided (Fig. 20). These cases are uncommon, and they often give disappointing results. The patient usually has become so expert in using the digits he possesses that he finds any appliance an encumbrance. Moreover some patients, after attempts at surgical reconstruction, have scars in awkward situations, possibly hyperaesthetic and sometimes associated with contractures. In consequence of such unsuccessful surgery the patient's morale may be low.

Some patients in this group come for the provision of a purely aesthetic prosthesis, for instance to replace absent digits. These cases, too, may give disappointing results because the structure of the natural hand is often such that the prosthesis cannot be mounted to look natural and inconspicuous; in any case,

the prosthesis is inevitably an encumbrance, and it is often quickly discarded (Fig. 21).

Multiple and bizarre deformities—This group provides the most difficult problems in upper limb prosthetics. The deformity commonly affects both sides. The general appearance is usually more or less grotesque and the patient is inevitably sensitive about this. The deformities are usually such that it is impossible to make a prosthesis hang in a natural position. The patient has usually achieved such skill with the deformed hands that the application of prostheses, which necessarily enclose the hands, so impairs function at first that he feels frustrated and may abandon the attempt. From this point of view, when both arms are deformed, it is advisable to approach the prosthetic management on one side at a time, and the less useful side should be attempted first.

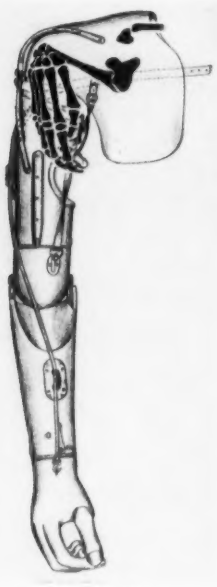

FIG. 22

FIG. 23

Figure 22—Severe congenital deformity of upper limb. Modified conventional above-elbow prosthesis fitted to limb, using shoulder cap for suspension. The elbow lock is operated by the digits by means of a toggle bar. Flexion at the elbow and manipulation of thumb or split hook is operated by separation of scapulae in rounding shoulders. The deformity was bilateral. Figure 23—Same case as shown in Figure 22. This shows the extent of the rehabilitation that may be achieved in cases of this severity.

The fused elbow joint presents problems of its own. If the length of the arm as a whole is full or nearly full the patient is prevented from reaching his mouth, and indeed from reaching the head and neck and much of the upper half of his body. A prosthesis cannot provide this function without being disproportionate. There is no satisfactory prosthesis for a deformity of this sort, and the provision of a surgical pseudarthrosis must be considered, especially when the deformity is bilateral.

Three unusual cases of severe double deformities have been seen. In each the long bones of one arm were shorter than in the other, but the anatomical features were substantially the same. The hands lacked one or two digital rays but otherwise were fairly normal. They articulated through the wrist with a short forearm composed of a single bone which probably represented the upper end of the ulna fused to the lower end of the radius. An elbow joint

of sorts was present, and a short humerus terminated abruptly at its proximal end, where it lay some distance below an indefinite glenoid. There were sharp contractures of all the joints, so that the arms were held in much the position of a dog's forepaws when begging. These patients were highly intelligent and used their short limbs remarkably well. They have been fitted with prostheses of definite, if limited, usefulness (Figs. 22 and 23).

Three patients have been seen with total or almost total absence of the upper limb. They had acquired astonishing skill in the use of their feet: one woman did exquisite needlework in this way. She did not persevere with the prostheses that were supplied because their function was limited and she was, at the age of forty-two, too set in her ways to learn. The second patient is fully rehabilitated and in employment as an accountant. The third is aged fourteen. Fitting is being undertaken and is promising well. Pectoral cineplasty has been considered in this case but, in addition to parental resistance to the consequent mutilation, it was not felt to offer much success because the chest was narrow and the range of movement of the tunnel would have been small.

Flail arms (eight cases)—Prosthetic technique can be applied with benefit in certain cases of flail or partly flail arms. For instance, it may be possible to provide voluntary flexion of a flail elbow by using a harness like that used for the above-elbow prosthesis mounted to an elbow cage. If the hand is functionless, a device can be fitted to a suitable palmar splint so that a split hook or other prosthetic tools can be carried and operated. Control of the scapular muscles is, however, a prerequisite of success in these cases.

It will be realised that the types of deformity described above are by no means comprehensive and that the possibilities of individual variation are infinite. Each case must be taken on its merits, and many demand the utmost technical ingenuity. The closest liaison between surgeon and prosthetist is demanded at all stages in the construction of the prosthesis and, when difficulties arise, an orthopaedic opinion should be sought on the possibility of improving the limb surgically. The plastic surgeons are able to help in selected cases.

SUMMARY

1. Congenital defects of the extremities are described. Although the detailed anatomy is infinitely variable, a broad classification in relation to prosthetic management has been suggested.

2. Most patients with these deformities can be fitted with a prosthesis without major surgical intervention. With this they will have at least as good function as they would have after amputation. A plea is made for a conservative attitude in this respect. It is suggested that recourse to amputation should be confined to cases in which prosthetic equipment falls short of functional and cosmetic requirements, and that, when possible, it should be deferred until the child is old enough to share in the decision.

3. The prostheses applicable to the various types of deformity are briefly described.

4. The application of similar techniques to cases of acquired shortening is mentioned.

5. The incorporation of certain features of artificial arms in flail arm splints is discussed.

I am indebted to the Chief Medical Officer, Ministry of Health, for permission to publish this paper. My thanks are also due to Mr H. J. Seddon for advice and encouragement in preparing the script and illustrations, to Mr J. S. Barham for the drawings, and to all those who have referred patients to me, in particular Mr Leon Gillies.

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TREATMENT OF OSTEOCHONDRITIS DISSECANS

I. S. SMILLIE, DUNDEE, SCOTLAND

It has been known for more than a decade that osteochondritis dissecans of the knee joint in children will heal with rest or even spontaneously (Decker 1938, Wiberg 1941, Strange 1944, Smillie 1946, Van Demark 1952, Green and Banks 1953). This capacity is lost with maturity and may not extend beyond adolescence (Wiberg 1943). Current treatment thereafter consists of symptomatic removal of the loose bodies which separate into the joint; and months or years later, of palliative measures directed to the pain of the osteoarthritis which develops in lesser or greater degree depending on the size and location of the lesion and the physical demands of occupation.

This paper records the experience of an attempt to treat osteochondritis dissecans in a more idealistic way. It confirms the possibility of healing in children by conservative means. It proposes to show that timely operative intervention can prevent separation of fragments and result in healing. Finally, it proposes to show that timely operative intervention can restore the anatomy of the part and result in healing even after fragments have separated.

COMPARISON WITH FRACTURES

Although it is axiomatic that treatment be related to cause, it is not intended on this occasion to re-enter the controversy about the etiology of this mysterious condition; but the reader's indulgence is sought for an over-simplification of the situation if the lesion is regarded as a fracture in order that the principles of fracture treatment can be applied.

It is characteristic of osteochondritis dissecans of the knee that the many stages in the pathological anatomy which exist, before the last isthmus of cartilage or ligament gives way, are represented by not dissimilar radiological appearances. But whether the overlying articular cartilage is intact, as it may be, or indented, or soft and raised above the surrounding surface, or partly separated, the feature common to all is an area of horizontal cleavage in the superficial layers of the underlying bone. The horizontal cleavage represents the fracture line. It probably originally contained blood, but in the absence of immobilisation it does not heal but proceeds through the various stages of delayed union to established non-union. In the final act, the smaller fragment, consisting of dead bone but live articular cartilage, is cast into the joint as a loose body. Osteochondritis dissecans, however, differs from other fractures in that it is never seen in the recent state. Unfortunately, the symptoms, at all stages save the dramatic locking of the final loose body, are ill-defined and transient; years may pass before the patient gives the opportunity for diagnosis. Treatment is thus determined by the stage at which the fracture is presented. Each demands different methods comparable with those in current use whereby delayed union is treated by rest, possibly supplemented by some method of improving local blood supply; established non-union by freshening of the bone ends, possible internal fixation to maintain alignment, and rest.

SPONTANEOUS HEALING

There are numerous references in the literature to spontaneous healing with a variety of interpretations of the meaning of spontaneous. "Treatment" in these "spontaneous" cases has varied from limitation of activity (Wiberg 1941) to plaster immobilisation (Van Demark 1952) or even complete bed rest for six months (Decker 1938). While it is recognised that true spontaneous healing can occur, and indeed is in keeping with the fracture analogy propounded, it is probably unwise to take no more action than to keep a child under observation for the two years (Wiberg 1943) to seven years (Green and Banks 1953) required,

when methods of therapy exist from which a return to radiological and clinical normality can be expected in a relatively short time. Further, if it is accepted that the condition heals spontaneously, or by immobilisation alone, it must also be accepted that a point may be reached in the pathological anatomy when the process is irreversible. Observation may be dangerous; but the younger the child the greater the tendency to return to normal and the less will be the risk.

True spontaneous healing was not observed in this series.

TABLE I

SEX AND AGE OF PATIENTS TREATED BY THE THREE METHODS DESCRIBED, AND SITE OF LESION

Method of treatment	Case number	Sex	Age	Site
Immobilisation only	1	M	10	Knee
	2	M	11	Knee
	3	M	11	Knee
	4	M	13	Knee
	5	M	15	Knee
Drilling+ immobilisation	6	M	16	Knee
	7	M	16	Knee
	8	M	22	Knee
	9	M	28	Knee
	10	M	14	Knee
	11	M	10	Knee
	12	M	15	Knee
	13	M	17	Knee
	14	M	13	Knee
	15	F	30	Ankle
	16	M	14	Knee
	17	M	14	Knee
	18	F	22	Knee
	19	F	13	Knee
	20	M	31	Knee
	21	M	14	Knee
	22	M	21	Ankle
Drilling+ nailing+ immobilisation	23	M	14	Knee
	24	F	15	Knee
	25	M	19	Knee
	26	M	18	Knee
	27	M	20	Knee
	28	F	22	Knee
	29	F	17	Knee
	30	M	16	Knee
	31	M	23	Knee
	32	M	18	Knee

IMMOBILISATION

It is probable that no treatment except immobilisation would be necessary in osteochondritis dissecans if the diagnosis could be made early enough; but the very features on which the radiological diagnosis is based, namely, relative density of the bony element of the fragment, or sclerosis of the base of the crater, indicate that the condition has existed for some time. Sufficient operative experience has been accumulated to indicate that the possibilities of healing by immobilisation alone are limited. In these circumstances, it is not proposed to attempt to define the indications for conservative treatment, but to record that three cases, treated ten years ago, healed in from three to six months. In each, the patient was relatively young, the lesion small and the sclerosis minimal. In a further two, immobilisation was not deliberate; it occurred incidentally in small symptomless lesions noted in the course of routine radiological investigation of recurrent subluxation of the patella. On completion of the treatment of this, the osteochondritis dissecans lesions were noted to be healed.

BACKGROUND TO REPARATIVE MEASURES

Drilling—At certain stages in development, before the loose body is discharged into the joint, the lesion has all the radiological appearances of an ununited fracture, with opposed surfaces of sclerotic bone and an intervening clear space. In the ordinary ununited fracture the radiological clear space represents dense fibrous tissue. In osteochondritis it is an actual space; and yet the overlying articular cartilage may be intact or merely depressed as a result of loss of support from absorption of bone. This is the type of case to which an operation to produce a fresh blood supply to both sides of the fracture, but with the minimum of interference with the overlying articular cartilage, is particularly applicable.

Multiple drilling of opposed sclerotic fragments in an ununited fracture in order to introduce a new blood supply has been practised since before the first world war (Wildey 1915). The method has gradually fallen into disfavour in the face of newer and much more certain

FIG. 1

FIG. 2

Case 25—The massive loose body, which consisted of a large proportion of the weight-bearing surface of the medial femoral condyle, had been free in the joint for at least six weeks.

methods of promoting union. There are, however, special circumstances in osteochondritis dissecans which make the method applicable, in particular the absence of a barrier of dense fibrous tissue between the fragments. The penetration from without inwards of the small fragment through the sclerotic zone of the condyle to a source of blood supply can be expected to result in the filling up of the entire space between the fragments with blood clot, which would be transformed into granulation tissue by capillaries growing out from the host and thus form a source of blood supply for the dense bony fragment.

Drilling and internal fixation—The follow-up of cases from which a massive loose body, consisting of a large part of the weight-bearing surface of the medial femoral condyle, has been removed provided the stimulus to attempt to repair the defect. The result of operation, even had it failed, could not have been worse that the disaster that occurs in any event. But there was no reason to expect failure. The articular cartilage of a loose body is alive and

proliferating; the bony element no more dead than before discharge into the joint; and it was known that before separation it could be revascularised from a suitably prepared bed.

The original case of the series in which the loose body was retained and healing occurred

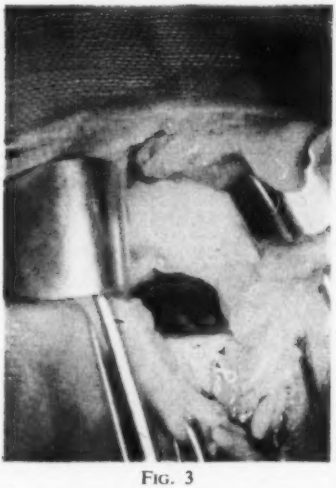

FIG. 3

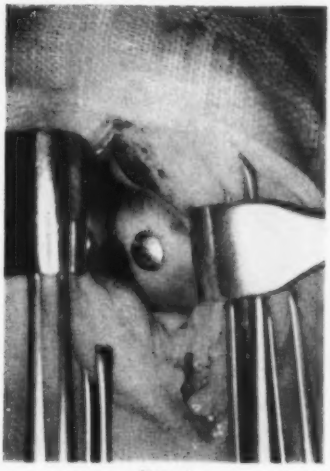

FIG. 4

Case 25. Figure 3—The crater. Figure 4—Articular cartilage at exploration fifteen weeks later. Replacement is imperfect; but the screw has provoked no reaction.

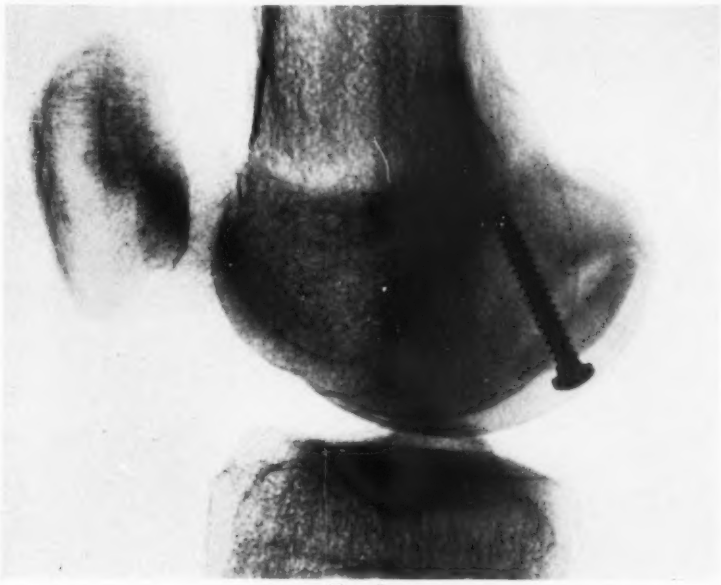

FIG. 5

Case 25—Radiograph immediately after replacement of the loose body and fixation with Vitallium screw.

has been recorded before (Smillie 1951). It was appreciated at that time that the risk of redisplacement after operation had not been eliminated and the possible use of internal fixation was proposed.

In the first case in which internal fixation was used, the loose body, which was of massive type, had been free in the joint for six weeks and it had to be pared down to fit the crater. Some form of fixation was essential, and it was effected by means of a single Vitallium screw. Fifteen weeks later, when the density of the fragment approached that of the surrounding bone, the joint was reopened to remove the screw. At operation it was seen that healing was complete, but there was some irregularity of contour from depression of one extremity below the general surface. The screw had provoked no reaction.

In the second case of the same massive type, greater difficulties of accurate replacement were encountered because of tissue loss. A screw was again used for fixation. At re-exploration the lesion had healed but the fit had not been quite accurate and the impression was gained that some absorption of articular cartilage had occurred adjacent to the small raw areas of

FIG. 6

FIG. 7

Case 25—Antero-posterior and lateral radiographs nine weeks after removal of screw and twenty-four weeks after internal fixation of the fragment. Radiological healing is complete.

bone which had been left exposed. The appearance of thinning of cartilage adjacent to an abnormal source of blood supply determined the decision early in the series not to use bone grafts or other reaction-promoting material as a means of internal fixation. The screw had provoked no detectable reaction (Figs. 1 to 7).

It was at this stage that it was realised that a screw, while possessing certain advantages, was not the ideal method of fixation. It is difficult to introduce and indeed the lesion may be in such a position that insertion is impossible. Further, once the screw is inserted no adjustment of alignment is possible. Consequently, in the third case, in which two large fragments were present, small pins, like the common commercial pins used in cloth but constructed of stainless steel wire, were used. Although they served the purpose, they were unsatisfactory in that a tendency to bend made them difficult to insert and when removed they were found to be eroded immediately distal to the heads, presumably because of the heat used in manufacture.

In the fourth, and in all six subsequent cases, stainless steel nails, one or one and a quarter inches long and of one-sixteenth of an inch in diameter, without heads but with a groove at the extreme proximal end to facilitate removal, were used (Fig. 13). The nail is held and inserted with a hollow punch incorporating a depth indicator. The final driving home is accomplished with a punch so constructed as to avoid damage to the articular cartilage (Fig. 8).

TECHNIQUE OF OPERATION

The operation is performed under tourniquet with the knee flexed over the end of the table as for excision of a semilunar cartilage. The incision is that used for removal of the medial cartilage (Smillie 1946), slightly enlarged in both directions but avoiding the infra-patellar branch of the saphenous nerve. The non-destructive nature of the approach is stressed. The procedure is justified only if the exposure used is innocent of permanent impairment of function. Access to the classical site varies with sex, conformation, and size of fat pad. Consequently the use of the three sizes of long-bladed knee joint retractor (Smillie 1946) is recommended. Division of the anterior and antero-central attachments of the semilunar cartilage should, if possible, be avoided.

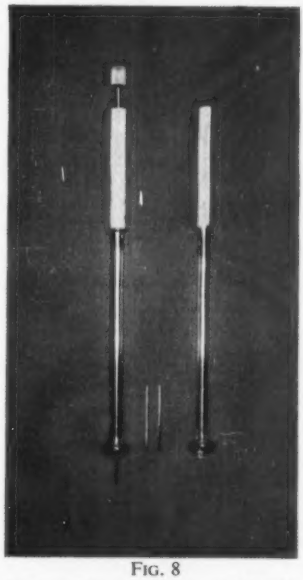

FIG. 8
Instruments—Nail gun and punch. The nails illustrated are one and a quarter inches long.

The next step is determined by the nature of the lesion:

1. The loose body is quite free, as in the uncommon massive variety, or lying in the intercondylar notch attached by a few strands of posterior cruciate ligament, as frequently occurs at the classical situation. In these circumstances the crater is prepared by excising any fibrous tissue that may line the margins and by drilling the base. In the latter measure the sclerotic bone will be found to be much harder than expected and time will be saved by the use of a fine-pointed gouge and hammer. If the loose body retains a ligamentous attachment this is preserved and any drilling of the bony element carried out within the joint using a fine sharp-pointed instrument such as a length of Kirschner wire. If the loose body is free the facility with which it can be replaced is not unnaturally related to the interval between displacement and operation. Paring of the proliferating margins must take place outside the joint; and the only means by which it can be held without damage is the gloved forefinger and thumb moistened with sterile saline. After paring, the fragment is returned to the crater and adjusted to the surrounding surface as accurately as possible. The direction in which the nail is inserted is determined to a large extent by the position of the lesion and by the access available. It cannot always be driven at right angles to the surface. Occasionally a second nail may be necessary. If the semilunar cartilage has been detached it is replaced and the fine catgut sutures are buried within the fat pad (Figs. 9 to 15).

2. The loose body has not separated but is outlined by granulation tissue protruding through a recent fissure, or by fibrous tissue lining a well established gap; the body is attached laterally by tags of posterior cruciate ligament and medially by an isthmus of intact articular cartilage. In these circumstances a decision must be made whether to leave the potential loose body undisturbed and treat by drilling alone, or to divide the isthmus of cartilage and hinge the loose body laterally on the ligamentous attachment in order to gain access to all aspects of the lesion. The choice will depend on local conditions. So far, the latter method has been favoured as less destructive of articular cartilage and more certain of success even if it did entail the use of internal fixation.

FIG. 9

FIG. 10

Case 28—Radiographs to show site and size of lesion.

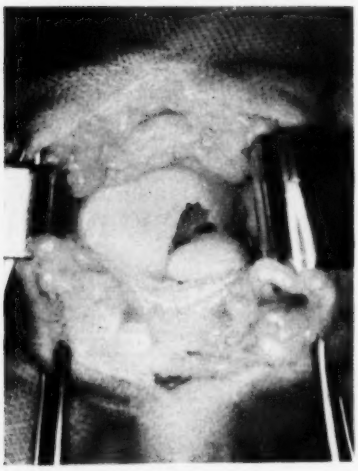

FIG. 11

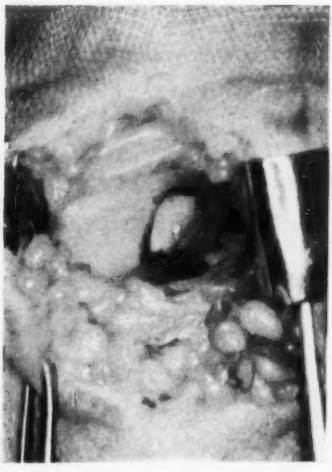

FIG. 12

Case 28. Figure 11—Crater and adjacent loose body. Figure 12—Appearance after drilling, replacement and introduction of nail. The loose body is slightly depressed in relation to the surroundings.

FIG. 13

Case 28—Post-operative radiograph which shows groove in nail to facilitate extraction.

FIG. 14

FIG. 15

Case 28—Antero-posterior and lateral views six weeks after removal of the nail. Radiographic healing is complete, but a slight depression can be seen in the contour of the condyle.

3. No lesion is visible on the articular cartilage; or the site is indicated by a shallow groove or depression. This is the type of case to which simple drilling can be applied. The first step is accurate localisation of the lesion. To this end inspection, related to the radiographic findings, may be all that is necessary. Sometimes, although the cartilage is intact, a search in the intercondylar notch above the rolled edge of the articular surface will reveal tags of fibrous tissue protruding from a fissure which leads into the horizontal cleavage. The actual fissure cannot be seen but the point of a button-hook retractor can be inserted into it. If no indication of the site of the lesion exists, or if the indications are indefinite, radiographs with markers of Kirschner wire in position should be secured to avoid the possibility of error (Fig. 21).

FIG. 16

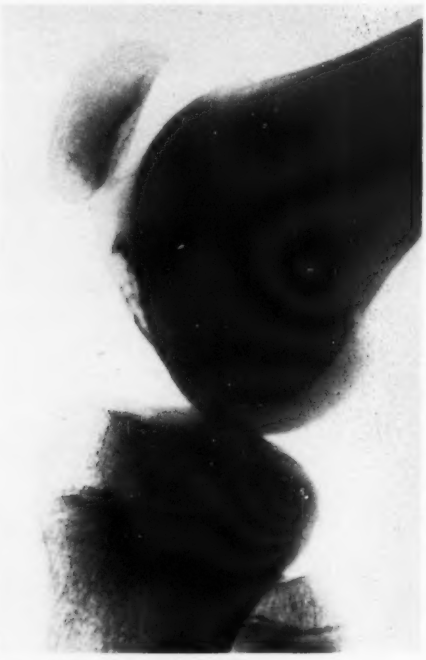

FIG. 17

Case 14—Extensive radiological lesion.

A point is selected at about the centre of the bony element and a small stab wound inflicted on the articular cartilage through which the " drilling " is performed. Originally a fine diamond-pointed drill was used, but experience has shown that perforation of the area in every possible direction consistent with the use of a small common point of entry is accomplished most easily with a fine sharp-pointed instrument such as a length of Kirschner wire driven directly inwards by hand (Figs. 16 to 20).

AFTER-TREATMENT

The factor that has influenced after-treatment has been the need to secure at least right-angled flexion to gain access to the nail. Initially the joint is treated exactly as if a semilunar cartilage had been removed; but in the third week, instead of permitting a return to weight bearing, mobilisation proceeds until it is clear that full flexion is attainable. Thereafter a plaster excluding the foot is applied in extension and the patient is permitted to get up

FIG. 18

Case 14—The site of the lesion is indicated by a raised area and adjacent depressed zone of darker colour. The articular cartilage is unbroken.

FIG. 19

FIG. 20

Case 14—Antero-posterior and lateral views twenty weeks later. Radiographic healing is complete.

using a patten and crutches. Quadriceps exercises, in the form of muscle setting, together with straight-leg and loaded-straight-leg raising, are practised at hourly intervals from the fourth day. At the end of twelve to sixteen weeks, depending on the estimate of healing time, the plaster is removed, radiographs are taken and remobilising exercises are begun.

Removal of the nail—If internal fixation with a nail has been used the nail is removed when the requisite degree of mobility has been attained by active means. The forcible flexion of a stiff joint under anaesthesia is likely to provoke undesirable reaction and delay recovery. In this respect, if, at the original operation, a torn semilunar cartilage is found underlying a lesion which warrants the use of internal fixation, it is desirable to defer the excision of the cartilage until the second operation when the nail is removed in order that the normal after-treatment of a cartilage operation can be pursued.

FIG. 21

If doubt exists about the exact position of the lesion, radiographs with a marker of Kirschner wire in position are taken to avoid the possibility of error.

The scar of the original incision is excised. The access required is minimal and should not necessitate division of the anterior and antero-central attachments of the cartilage. The nail is extracted by removing a small piece of articular cartilage from the nearest side with a very small gouge and then hooking the gouge point into the groove on the neck of the nail.

The further treatment, and especially the decision as to when to permit weight bearing, depends on the assessment of the degree of healing determined by radiographs and the visual evidence at operation in relation to the degree of recovery of the quadriceps.

OTHER JOINTS

The ability to treat osteochondritis dissecans by the operative methods described is determined by the size of the fragment, and especially of the bony element, in relation to the size of the joint. In the elbow, for example, the nature of the lesion is such as to make the present methods inapplicable. The condition is, however, more important in terms of loss of function in the weight-bearing joints. Two attempts have been made, therefore, to treat lesions in the talus by drilling. It is emphasised that these are the only cases so treated; that the approach is of necessity relatively destructive; and whether the end-result justified the means is almost impossible to assess, except in so far as no other method of treatment was available in the circumstances except arthrodesis.

In the first patient, a woman aged thirty, the lesion was located by tomographs on the postero-medial aspect. Direct access was possible only by a medial trans-malleolar approach. In order to effect absolute accuracy of replacement, a screw was inserted through to the malleolus into the tibia and then partly withdrawn before the bone was divided with a fine osteotome at the point where the vertical and horizontal portions of the articular surface meet. The fragment was retracted downwards to give good access for the drilling of a lesion in which the articular cartilage was unfractured. The operation was completed by replacing the malleolus and driving home the screw. After operation the part was immobilised in a plaster for four months, in the first two of which a patten and crutches were used, and in the

second weight bearing was permitted. The lesion at this time appeared to have healed radiologically. After three further months of exercises the patient declared herself symptomless except that the ankle tired more readily.

In the second patient, a man aged twenty-one, the lesion was located by tomographs on the postero-lateral aspect. Direct access was possible only by a lateral trans-malleolar approach. A straight incision was made over the fibula slightly anterior to its most prominent aspect. A small opening was made in the capsule immediately anterior to the fibula in order to locate the level of articular surface of the tibia. A long, oblique incision from before backwards and upwards, beginning at the joint line, was then made in the periosteum of the fibula. A horizontal hole was drilled at the mid-point of this incision and a self-tapping screw inserted. The screw was then withdrawn and an oblique osteotomy, in direction from before backwards and upwards and inclining posteriorly, was made with a fine saw. The malleolus, together with the peroneal tendons, was retracted backwards. The fragment, which was larger than expected, was loose, at least on its lateral aspect; the extent of the medial margin could not be seen. Drilling of the crater was accomplished through the lateral fissure with a Kirschner wire.

When the lateral malleolus was replaced and the foot dorsiflexed, the fragment remained in reasonable apposition to the parent bone. Internal fixation would have been desirable if recovery of the nail had been possible without detriment to the joint. The incision was closed by reintroducing the transverse screw and suturing the periosteum.

At the end of operation a pressure bandage and plaster were applied. When the sutures were removed a skin-tight plaster was substituted and the patient permitted to get about for the next three months using a patten and crutches. In the fourth month weight bearing was permitted in the plaster.

RESULTS OF TREATMENT

No claim is made to have solved the problem of the treatment of osteochondritis dissecans; far from it. It is not possible to assess results in a condition that in the natural course of events produces traumatic osteoarthritis in greater or lesser degree in a greater or lesser period of time, depending on such a variety of factors. It is claimed, however, in the cases recorded (with the exception of Cases 21, 22, 30, 31, 32) to have eliminated the symptoms for which the patient originally reported, namely, pain, instability and recurrent effusions; to have produced radiographs in which the lesion appears to have healed; and to have produced visual evidence, in the seven cases in which exploration to remove the means of internal fixation was necessary, of restoration of the articular surface, even after a loose body had separated.

POSSIBLE DEVELOPMENTS

The greatest difficulty that has been encountered has been the accurate replacement of the fragment, which tends to sink below the level of the surrounding articular surface as a result of loss of bone from the base of the crater. This can be only partly overcome in the preparation of the bed by the raising of some bone to a higher level (Smillie 1951). Consideration has therefore been given to the possibility of adding autogenous or homogenous cancellous tissue. This matter has not been pursued so far. It was felt that to complicate a procedure under trial with an additional manoeuvre of unknown effect was unjustifiable.

Homogenous grafts—No solution has been offered in the case untreatable by the methods described. Such circumstances, and those referred to above, prompt the suggestion that the affected area be excised by trephine and replaced by frozen homograft of articular cartilage and bone of suitable surface contour. This idea, too, has not been pursued in the absence of reliable information regarding the reaction of articular cartilage to freezing. It is of interest, however, that Ehalt (1955) has reported the results of experiments showing that the viability of frozen cartilage cells is not lost for four or five weeks. He records the replacement by

massive bone and cartilage graft of a tuberculous focus in the lower femoral epiphysis of a boy aged five; and of the articular surface of the patella for chondromalacia in a woman aged twenty-seven. The possible application to osteochondritis dissecans was mentioned. If the experiments are confirmed it is evident from the experience of this series that the transference of banked cartilage and bone to a defect in the femoral condyle presents no serious technical difficulties. To attain perfection, whole right and left condyles from youthful subjects would probably be required and, according to Ehalt, discarded at intervals of six weeks. If the practical difficulties of securing, preparing, storing, and constantly replacing such material can be overcome, a spectacular advance in the treatment of many more conditions than osteochondritis dissecans will be possible.

SUMMARY

1. The record is presented of an attempt to treat osteochondritis dissecans on idealistic lines.
2. The operative technique to be adopted in the various circumstances likely to be encountered in the knee joint is described. Two cases affecting the talus are recorded.
3. The radiological appearance has become virtually normal in twenty-seven cases (the remaining four are recent); healing has been observed directly in seven cases in which a second operation to remove the means of internal fixation was necessary; and the patients' complaints have been eliminated, but the long term results of treatment are unknown.
4. Suggestions are made for possible developments in the technique of operation.

I acknowledge with gratitude the help of my colleagues of the Eastern Region (Scotland) Orthopaedic Service: Mr J. Hutchison, Mr I. D. Sutherland, Mr G. Murdoch, Mr R. D. Muckart, Mr G. L. Clark and Mr C. S. Campbell, who, by referring their cases to me, have made possible the accumulation of the material; and of Mr Peter Fraser, Chief Technician of the Orthopaedic Workshop of Bridge of Earn Hospital, Perthshire, who was responsible for the development of the instruments and the nails.

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OSTEOCHONDRITIS DISSECANS IN ASSOCIATION WITH DWARFISM

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The cause of osteochondritis dissecans is still disputed. Axhausen (1912) suggested that the lesion could be embolic in origin, but Fairbank (1933) and Smillie (1951) believed that trauma was more likely to be responsible. The occurrence of multiple joint lesions, with a hereditary tendency, was demonstrated by Bernstein (1925), by Wagoner and Cohn (1931), by Gardiner (1955), and by Pick (1955) who all described families in which two or more members were suffering from the disease. The occasional occurrence of multiple joint lesions in association with dwarfism has been reported, and Roberts and Hughes (1950) noted that one of their patients was a dwarf. Pick mentioned that the members of the family he described were under average height. No biochemical investigations have been recorded except in the one case described by Hay (1950).

FIG. 1

FIG. 2

Case 1. Figure 1—Photograph of the patient. Figure 2—Right knee showing flattening of the lateral femoral condyle. There is a loose body in the lateral compartment.

The existence of a constitutional factor underlying certain types of osteochondritis dissecans is now accepted, but no evidence has been produced to identify the nature of such a factor, although Roberts and Hughes suggested that it might be an endocrine disorder.

Three patients with osteochondritis dissecans, all well under average height, in each of whom several joints were affected, are reported here as further evidence of a constitutional upset in this condition.

Case 1—Woman aged twenty-eight years, only four feet four inches tall. The general appearance of the patient (Fig. 1) was that of a much younger person, and the secondary sex characteristics were poorly developed. Her hair was scanty and fine, the spine showed a

mild kyphoscoliosis, and there were numerous pigmented striae on the abdomen. The family history was of no significance, and her parents and two sisters were of average height. At puberty the patient complained of aching in her knees, hips and elbows, but it was not until the age of nineteen that she first complained of locking and instability of the right knee. This was due to a loose body in the joint, which was demonstrated radiographically and subsequently removed (Fig. 2). At operation the articular surface of the patella was found fragmented and an area of osteochondritis dissecans was noted in the medial femoral condyle. Two years later similar symptoms occurred in the same knee which necessitated another arthrotomy. Recently the patient complained of pain in the right hip, radiating down the inner side of the thigh to the knee, and a radiograph of the hip showed a loose body near the lower surface of the femoral head (Fig. 3). Radiographs of the thoracic spine revealed evidence of previous osteochondritis juvenilis (Fig. 4).

FIG. 3

FIG. 4

Case 1. Figure 3—Right hip showing deformity of the under surface of the femoral head and a loose body in the inferior aspect of the acetabulum. Figure 4—Thoracic spine showing a kyphosis and wedging of the vertebrae from osteochondritis.

Investigations—Because of the large number of biochemical tests undertaken, only abnormal results are recorded. Total serum protein was 7·9 grammes per 100 millilitres. Serum albumin was 2·8 grammes per 100 millilitres, serum globulin 5·1 per 100 millilitres, serum potassium 5·8 m.eq. per litre, serum calcium 3·4 m.eq. per litre, plasma inorganic phosphorus 5·2 milligrams per 100 millilitres. Follicular stimulating hormone was 40 mouse units per diem. The basal metabolic rate was 4 per cent below standard. A radioactive iodine test for thyroid activity showed a mild impairment of thyroid function and there was also a low flat glucose tolerance curve. All tests for renal function were normal. Gynaecological examination under anaesthesia showed a hypoplastic uterus, and microscopy of the endometrial mucosa revealed that the stromal changes were more fully developed than glandular ones for the phase of the cycle. These tests suggested an impairment in thyroid and parathyroid function with underdevelopment of the sexual glands.

Case 2—Man aged twenty-one years, four feet six inches tall. The patient (Fig. 5) had a high-pitched voice and the secondary sex characters were poorly developed. The family history was irrelevant, and his parents and three sisters were above average height. There was no previous illness of note, except for pains in the large joints and thoracic spine at puberty. At the age of sixteen he complained of pain in the right elbow, and radiographic examination showed an area of osteochondritis dissecans in the capitulum. Later the elbow locked and a loose body was removed from the joint, the site of origin being the capitulum (Fig. 6). Within a year similar symptoms occurred in both knees; loose bodies were demonstrated radiologically and removed at operation (Figs. 7 to 9). Recently a second operation was performed on his left knee, from which three loose bodies were removed. Although the articular surface of the patella was rough and fragmented the loose bodies appeared to arise from an area of osteochondritis dissecans in the lateral condyle of the femur (Fig. 7). A radiograph of the thoracic spine showed evidence of previous osteochondritis juvenilis (Fig. 10).

FIG. 5
Case 2—Photograph of the patient.

Investigations—Total serum proteins were 6·8 grammes per 100 millilitres. Serum albumin was 3·1 grammes per 100 millilitres, serum globulin 3·7 grammes per 100 millilitres, serum calcium 5·4 m.eq. per litre, plasma inorganic phosphorus 5·6 milligrammes per 100 millilitres; 17-ketosteroids were 7·3 milligrams per diem. Lipid phosphorus was 1·65 milligrams per 100 millilitres. Fasting serum total fatty acids were 2,340 milligrams per 100 millilitres as stearic acid. All tests for thyroid and renal function were normal. A flat glucose tolerance curve was recorded. There was no gross abnormality in the external genitals, but he

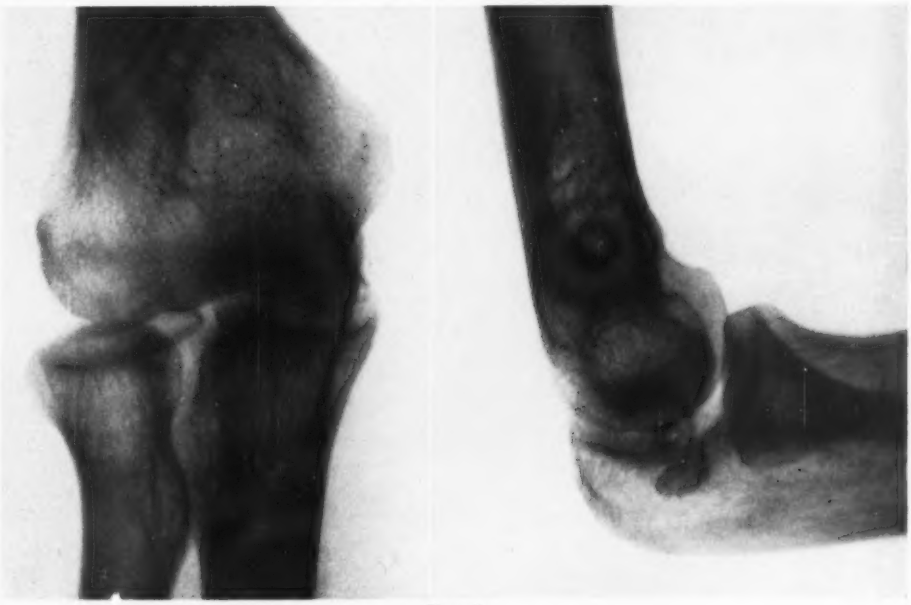

FIG. 6
Case 2—Right elbow showing loose body formation.

admitted diminished libido. These tests suggested hypofunction of the sex glands with a mild metabolic upset.

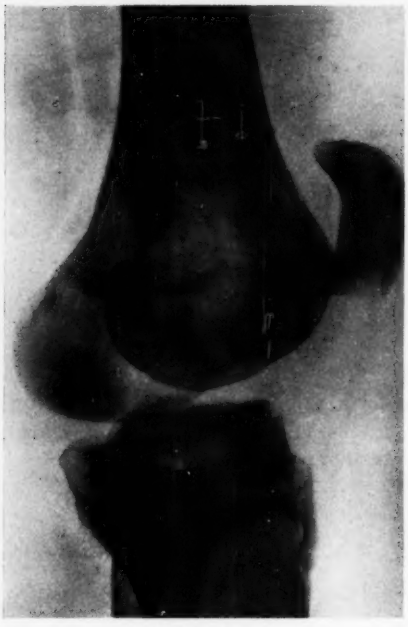

FIG. 7

FIG. 8

Case 2. Figure 7—Left knee with osteochondritic changes in the lateral condyle of the femur. Figure 8—Right knee showing deformity of the patella from osteochondritis of the articular surface.

FIG. 9

FIG. 10

Case 2. Figure 9—Skyline view of left patella showing osteochondritic changes and loose body formation. Figure 10—Osteochondritis juvenilis of the thoracic spine. .

Case 3—Woman aged twenty-one years, four feet five inches tall. When the patient was first seen her appearance was that of a child about eight years old (Fig. 11). Although late in

appearing, the secondary sex characters were normal, but her menstrual periods were scanty and irregular. The rest of the family were of average height, but a cousin suffered from loose bodies in both knees, and was of diminished stature. Initially the patient was referred from a rheumatic clinic because of pain in both elbows, and radiographs showed osteochondritic changes in the capitula of both joints (Fig. 12). Some months later the left elbow locked and radiographs showed a loose body in the joint (Fig. 13). Later she noticed similar symptoms in the right elbow, and a loose body was demonstrated radiographically. The elbows were explored and the loose bodies removed. A year later loose body formation necessitated a second operation on the left elbow. Radiographs of the right knee and ankle were taken after she had had symptoms in these joints, and further evidence of osteochondritis dissecans was found, but no loose bodies were seen (Figs. 14 and 15). This patient also had osteochondritis juvenilis in the thoracic spine (Fig. 16).

Investigations—Only the plasma inorganic phosphorus (4·6 milligrams per 100 millilitres) and the total fasting serum fatty acid (568 milligrams per 100 millilitres) showed abnormal figures. All tests for renal and thyroid function were normal. Gynaecological examination under anaesthesia revealed nothing abnormal, but microscopic examination of the uterine mucosa showed proliferative endometrium with a tendency to a cystic pattern. No conclusions were drawn from this patient's biochemical tests, but it is interesting to note that the plasma inorganic phosphorus was elevated in all three cases.

FIG. 11
Case 3—Photograph of the patient.

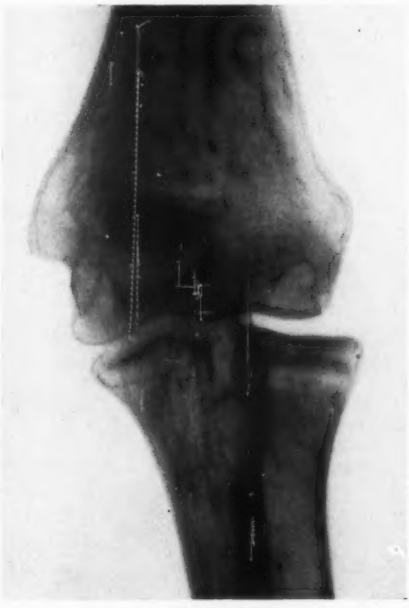

FIG. 12

FIG. 13

Case 3. Figure 12—Left elbow showing osteochondritis dissecans of the capitulum. Figure 13—Later radiograph showing loose body formation. The right elbow showed similar changes.

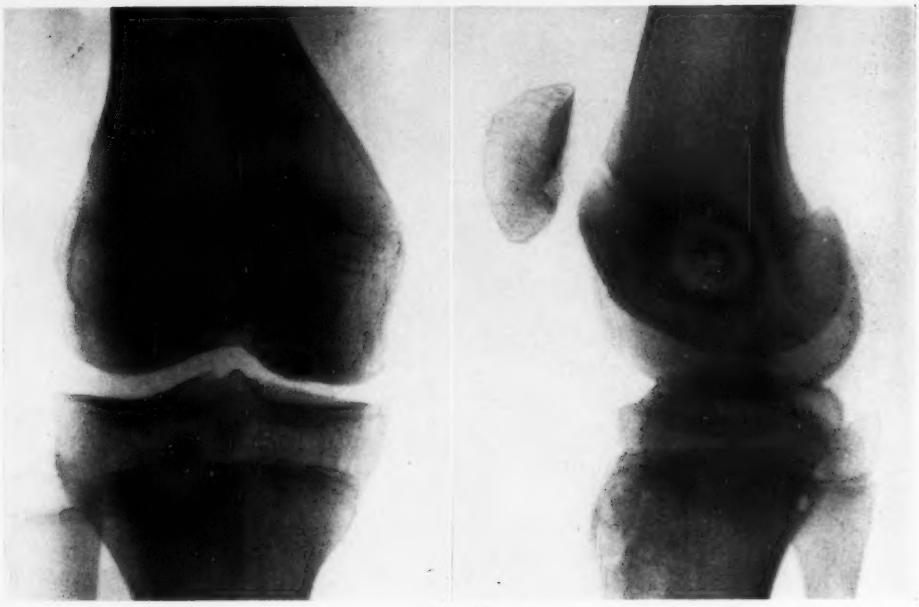

FIG. 14

Case 3—Right knee illustrating roughness of the articular surface of the patella and osteochondritis dissecans of the medial femoral condyle.

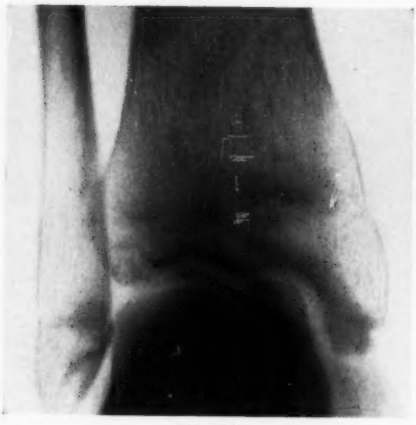

FIG. 15

FIG. 16

Case 3. Figure 15—Right ankle showing an osteochondritic lesion in the lateral aspect of the articular surface of the tibia. Figure 16—Mild osteochondritis juvenilis of the thoracic spine.

DISCUSSION

During their studies of endocrine dwarfism, Schaefer, Strickroot and Purcell (1939) were struck by the frequency of single and multiple chondro-epiphysial disturbances associated with hypothyroidism. Among the epiphysial disturbances that they listed was osteochondritis juvenilis of the thoracic spine, and this was a feature common to the three cases described above. Schaefer *et al.* also maintained that in a number of instances this endocrine imbalance adjusted itself as the patients reached maturity.

Although the first of my three patients alone showed impairment of thyroid and parathyroid function, there was some evidence to support the diagnosis of a mild endocrine imbalance in the second patient. There was no biochemical evidence of a glandular disturbance in the third case, but a careful study of the course of the disease suggested that she had passed through phases like the other two patients. It is notable that the condition was heralded in each case at puberty by a generalised aching in the joints in which loose bodies subsequently occurred, and that all the patients had a raised inorganic plasma phosphorus.

I would like to suggest that in these cases the underlying constitutional disturbance was an endocrine imbalance at puberty, which adjusted itself in varying degrees as the patients matured. This adjustment possibly accounts for the variation in the biochemical investigations in each patient in later life.

SUMMARY

1. Three patients suffering from osteochondritis dissecans in several joints, and all below average height, are described.
2. There was evidence of a constitutional upset in each case.
3. It is suggested that there was an underlying endocrine imbalance at puberty.

I wish to thank Mr J. Patrick for permission to report these cases, and Dr J. C. Eaton, in charge of the Biochemistry Department, for his help in the biochemical investigations.

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OSTEOCHONDRITIS DISSECANS OF THE HIP*

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This work is concerned with a particular type of osteonecrosis which, because of its spontaneous occurrence and its anatomical features, must be regarded as distinct from aseptic necrosis of the head of the femur occurring after severe injuries to the hip or in " caisson disease."

The osteochondritis dissecans discussed here was first described by Paget (1870) and named by König (1887). Its best known appearances are in the elbow and knee, whereas affection of the hip is distinguished by its rarity. It was described in France in 1932 by Moulonguet (who published later several articles about it). His study of the condition was very completely repeated by King and Richards (1940), who then found some thirty published cases, though in fact the present knowledge of the anatomical and radiological syndrome should considerably facilitate recognition. In the same way we found ourselves in a short time confronted with several instances of the condition, and, on reviewing the files of the orthopaedic clinic in Lyons covering the last fifteen years, we collected from them eight cases. One of these in particular is of a girl, nineteen years of age, treated in 1947 by one of us for a chronic arthritis of uncertain origin. Looking at the film again after an interval of eight years we were able to classify the condition under osteochondritis dissecans of the hip. At the same time this case made us appreciate the spontaneous development of the condition in a young subject. Comparison of our eight cases (Table I) with previously published observations induced us to renew the study of the condition.

PATHOLOGICAL ANATOMY

The anatomy of the lesion is well known from the findings at operation. The femoral head having been dislocated (an essential step in the full examination), one finds that on the whole the joint appears normal. The articular cartilage of the upper part of the head, outside the fovea capitus, is yellowish in colour, rather like old ivory. It is often wrinkled or "grained" and has been likened to the skin of the hand macerated under a wet dressing. This zone of cartilage can easily be depressed with a blunt instrument. When the cartilage has been divided, partial sequestration of the capital " nucleus " is revealed. The sequestrum represents the characteristic lesion of the disease. It occupies a cavity in which it can move slightly; it is easily removed, and then one can see that it resembles a fairly typical " joint loose body " with an upper surface of cartilage and a lower surface of fibrocartilage and an intermediate bony layer. It is circular, with a diameter of two to two and a half centimetres, thicker in the centre than at the circumference, and its general shape has classically been compared to that of an old coin. The base of the cavity is covered with fibrocartilaginous tissue. It all looks as if a portion of chondrifying tissue were sinking into the head in such a way as to become isolated (Fontaine 1953).

Although these are the typical anatomical features of the condition there are certain particular variations. Much more rarely the sequestrum is completely cartilaginous, and the affected part of the femoral head is covered with veritable blisters. Superficial sequestration of the infero-internal portion of the head in the joint space has been encountered. A cotyloidal site for the body is classical though we did not encounter a convincing case. Histological

* The translator, Professor Bryan McFarland, has retained some of the authors' forms of expression, though the translation is necessarily free.

examination demonstrates dead bone compressed between two layers of living fibrocartilage. Inflammatory signs were never found, nor were lesions indicating vascular obliteration (Soeur 1951).

ETIOLOGY

Two of our observations have particular interest. They are concerned with children who at the time of the first examination were eleven and twelve years of age (Cases 1 and 2). In the first the trouble had begun at the age of one year, and in the second at the age of ten months. This conforms with statements in the literature (Gold (1930) thirteen years, Francillon (1932) fourteen years, Müller (1933) fourteen and twelve years).

TABLE I

CLINICAL DETAILS IN EIGHT CASES OF OSTEOCHONDRITIS DISSECANS OF THE HIP

Case No.	Sex	Age	Clinical history	Radiographic appearance	Condition when examined first	Treatment	Result
1	F	11	One year: sudden onset. Pain	Typical: large sequestrum	August 1947. Limitation of movement	Plaster three months	April 1955: Subluxation with osteoarthritis (Fig. 2). Arthrodesis performed later
2	M	12	Ten months: insidious onset. Pain.	Typical: large sequestrum	October 1947. Movements full	Arthrotomy only	November 1949: normal function. 1954: farm labourer. No trouble
3	F	18	Two years: sudden onset. Pain	Typical: large sequestrum: half the head	March 1943. Deformity. Marked limitation of movement	Resection and remodelling	February 1944: ankylosed hip
4	F	20	One year: insidious onset. Pain	Thin sequestrum	February 1954. Normal function	No treatment	April 1954: normal hip
5	M	24	Three years: insidious onset. Pain	Typical: large sequestrum	September 1941. Muscle wasting. Limitation of movement	Cup arthroplasty	March 1942: hip mobile but painful
6	M	25	Two and a half years: insidious onset. Pain	A thick sequestrum from the inferior part of the joint space	June 1942. Deformity. Limitation of movement	Sequestrum removed	June 1943: No pain. Slight limitation. The hip was not radiographically normal
7	M	36	Six months: rapidly increasing pain	Typical: large sequestrum	March 1954. Deformity. Nearly complete ankylosis	Sequestrum removed and cavity packed	October 1954: no pain. Hip stiff but not painful
8	M	51	Sixteen months: sudden onset after violent trauma	Typical: large sequestrum and arthrosis	August 1953. Ankylosis	Acrylic arthroplasty	April 1955: Failure

When first seen our two patients were considerably over the age for Legg-Calvé-Perthes disease, and moreover their pictures were certainly characteristic of osteochondritis dissecans. This led us to consider again an absolute differentiation such as one has often wished to establish between these two conditions. It may be admitted that the appearance of a capital necrosis of the type of osteochondritis dissecans of the hip in the latter years of childhood—say from eleven onwards—may be a transitional phase between Legg-Calvé-Perthes and König's disease. An essential distinguishing feature, we think, would be the capacity for reconstruction of the dead nucleus, which is practically constant in the child of six to seven years with Legg-Calvé-Perthes disease, but most uncertain on the contrary from fifteen years onwards as in König's disease. Between these two ages there could exist intermediate cases

FIG. 1

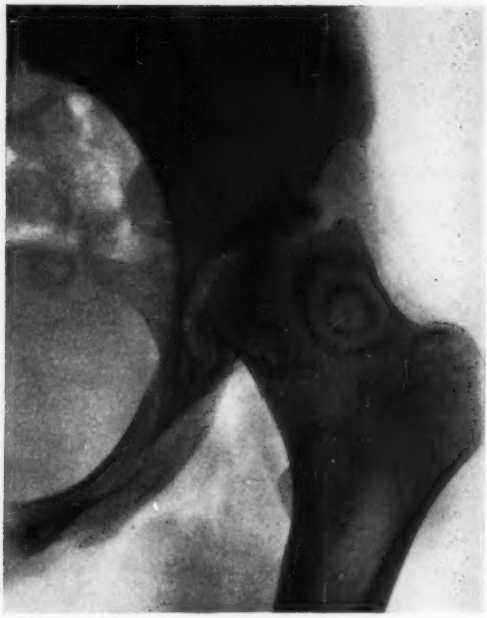

FIG. 2

Case 1. Figure 1—Osteochondritis of the left hip in a girl of eleven years. Early lesion diagnosed as osteoarthritis. Treatment: plaster for three months. Figure 2—Condition eight years after the first examination.

FIG. 3

FIG. 4

Case 2. Figure 3—Osteochondritis dissecans of the right hip in a boy of twelve years. Typical radiological appearances. Treatment: simple arthrotomy. (Radiograph immediately after operation.) Figure 4—Condition seventeen months later.

which can achieve normal or very nearly normal reconstruction, as is demonstrated in one of our cases (Case 2) though sometimes the hip may become seriously distorted (Case 1, Figs. 2 and 4). The difficulties of clarifying cause and effect are illustrated by one of our patients, a man of fifty-one years of age suffering from degenerative arthritis associated with osteochondritis dissecans of the hip. This man's trouble had started fifteen months before our examination and was associated with violent injury to the hip (Fig. 5). The possibilities are that his arthritis had resulted from injury to a hip affected by osteochondritis, which, though old-standing, had up to that moment been "silent," or that everything had happened as a result of the accident alone. Dr P. Moulonguet studied this case, which is the only one in our series in which we can point clearly to injury as a factor. All our other cases arose spontaneously. Moreover, in thirty recorded cases that we reviewed, injury was mentioned only four times. In our eight cases none was bilateral. Though clasically " bilateralité " is frequent we were in fact only able to find four cases out of thirty. We found none in which the condition was familial. Finally in two of our patients there was pre-existing malformation of both femoral heads. This factor has already often been mentioned and no doubt these slight dysplasias, because they upset articular mechanics, may favour the appearance of osteochondritis dissecans.

CLINICAL STUDY

Clinically we have nothing original to report. In the early stages there is always pain, and this is usually slowly progressive. Yet it can become acute and rapidly increase, as in three of our cases, in one of Fontaine (*loc. cit.*) and in one of King (*loc. cit.*). This first painful phase, which is sometimes long drawn out—up to twenty years—is followed by loss of function, which may be severe (Cases 7 and 8) and may go on to complete stiffness. Prolonged observation of the type which is secondarily bilateral has shown that the radiographic lesions appear long before the clinical signs. Contrary to the usual clinical picture, radiographic features are most characteristic and correspond in a precise manner to the anatomical findings. In the great majority of cases one sees the outline of a sequestrum situated in the supero-lateral pressure zone of the femoral head. It is long and narrow, and is thickened a little in the middle. It is usually about the size of the kernel of a small almond nut, but may sometimes take up to one-third or one-half of the surface of the head (Figs. 6 and 8).

The sequestrum is little different in density from that of the rest of the head; it is usually homogeneous, and the margin is always demarcated by a thin clear line. The lesion is entirely self-contained, except for a slightly crinkled appearance of the adjacent acetabular roof and occasionally co-existent arthritic changes. As has been pointed out, sometimes one finds the sequestrum situated in the lower and inner part of the joint space (Case 6, a case of Bergmann (1929), Fig. 9). Finally the lesion is at times of the " sequestre mince " type, which is seen as a simple irregularity of the surface of an otherwise normal femoral head. This is occasionally difficult to demonstrate and necessitates radiographs taken from varying angles (Fig. 7).

Given such appearances it is nearly always easy to recognise straightforward osteochondritis dissecans of the hip. Difficulty arises when there are secondary arthritic changes which mask the primary lesion. It is also true that somewhat comparable findings may be encountered in cases of epiphysial necrosis resulting from fractures of the femoral head or from dislocation of the hip. Then, however, the sequestrum is more opaque and is surrounded by osteoporosis. The same applies to caisson disease, in which the sequestrum is encased in a diffusely affected femoral head (Fig. 12). In these cases if the radiological interpretation is open to doubt the previous history provides the explanation of the cause. It may happen that in certain forms of coxalgia the diagnosis may not be quite clear. Reviewing fifty cases of primary coxalgia in the adult treated at this clinic we found two whose appearances recalled that of osteochondritis dissecans of the hip, and it was necessary to keep one of these under observation for a long time until the appearance of an abscess settled the question (Fig. 8).

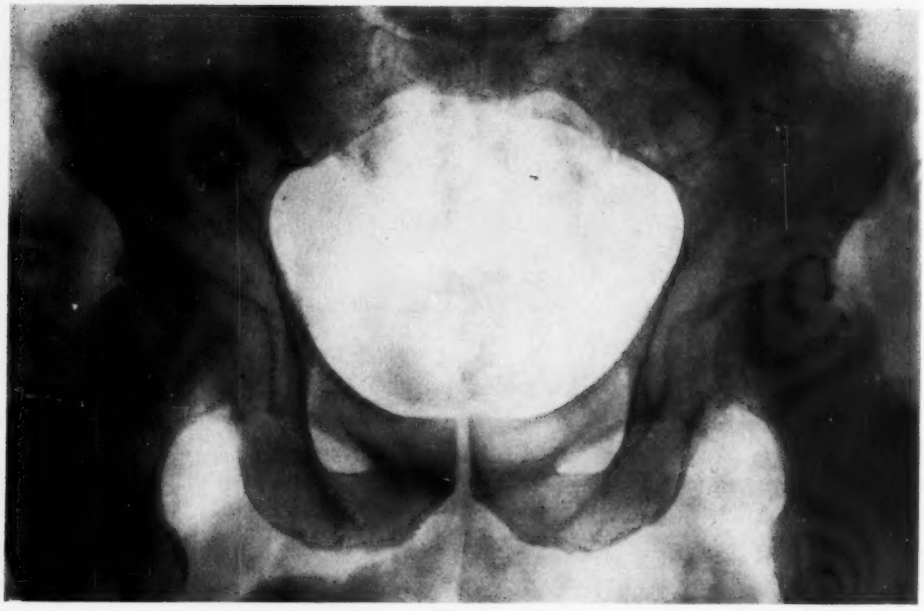

FIG. 5

Case 8—Osteochondritis dissecans of the left hip in a man of fifty-one years. Severe lesion associated with signs of osteoarthritis. Operative confirmation of the diagnosis of osteochondritis dissecans.

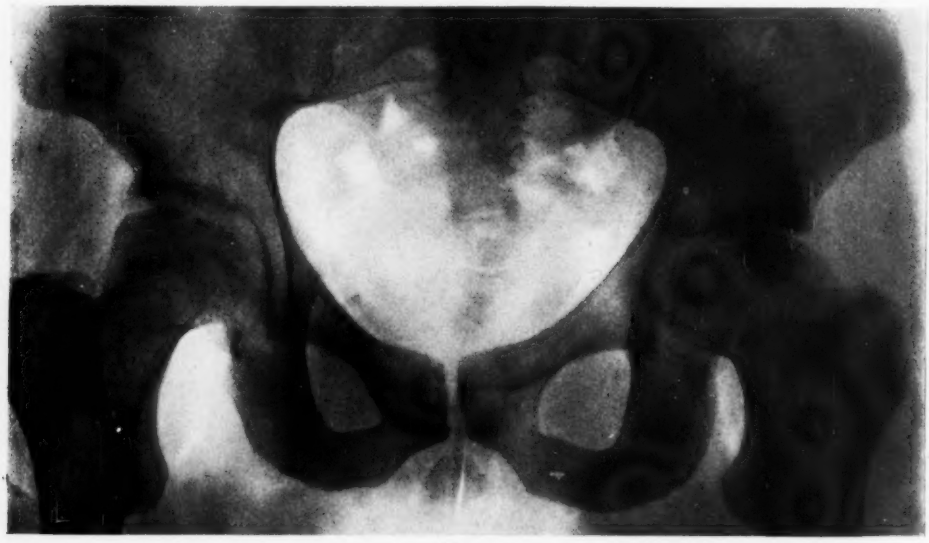

FIG. 6

Case 5—Osteochondritis dissecans of the right hip with typical radiological appearance. Distinct malformation of both femoral heads. Irregularity of the surface of the left femoral head, possibly representing a thin sequestrum.

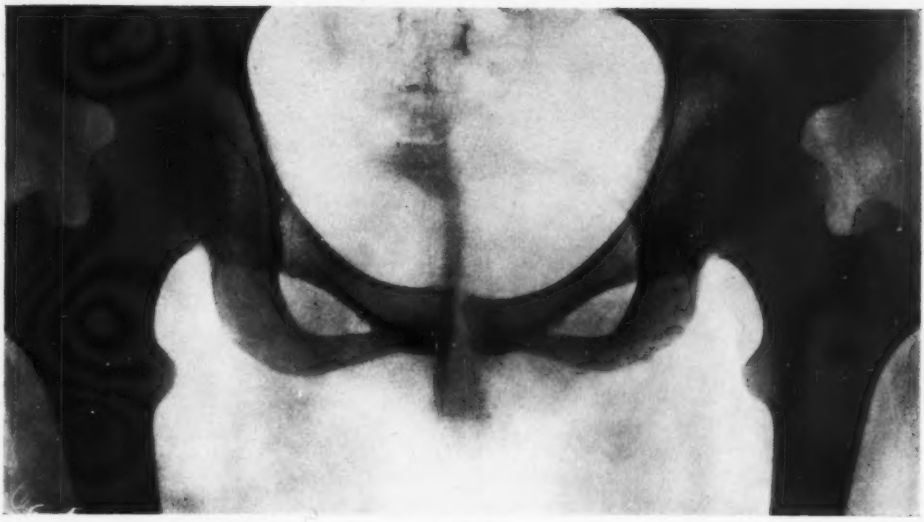

FIG. 7

Case 4—Osteochondritis dissecans of the left hip. Appearance of thin sequestrum. Distinct malformation of both femoral heads.

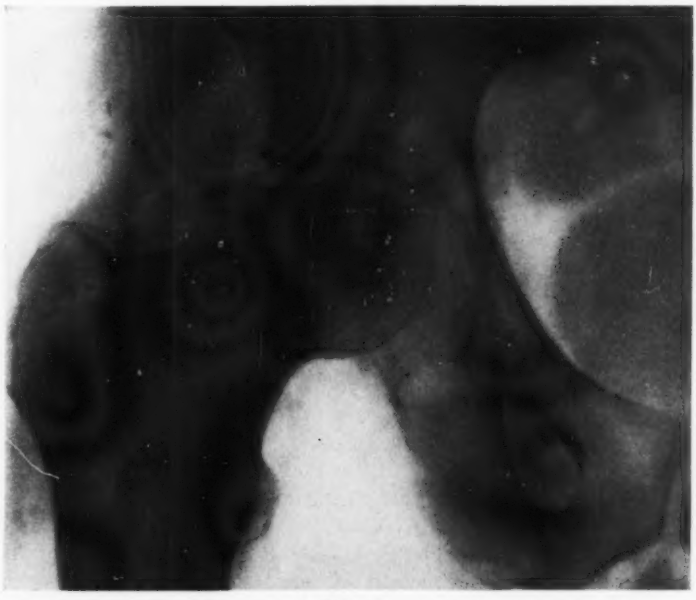

FIG. 8

Case 7—Osteochondritis dissecans of the right hip in a man of thirty-six years. Destructive form, presenting a major and rapidly progressive (six months) clinical picture. Clinical appearance of pseudocoxalgia. Operative confirmation of diagnosis of osteochondritis dissecans.

EVOLUTION

The course of the condition, as we have seen, is often prolonged. The end result is a severe impairment of function and a secondary arthrosis. In contrast to osteochondritis dissecans at other sites the necrotic nucleus never seems to act like a loose body free in the joint. There are cases, particularly in young people, where one has witnessed the regeneration of a subnormal head. Such was the case in one of our patients who was seen for the first time eight years ago (Case 2). But this period of observation is too short, and in practice a guarded prognosis must be given. All the evidence justifies the fear that osteochondritis dissecans of the hip will finally result in an arthrosis. It is therefore important to detect osteochondritis of the hip early and to treat the patient in such a way as to relieve the pain and improve the function and above all to prevent the occurrence of arthrosis. Even so the problem of that rational treatment is not yet perfectly resolved.

FIG. 9

FIG. 10

Case 6. Figure 9—Large sequestrum lying in the medial part of the joint space of the left hip. Figure 10—Condition six months after removal of the sequestrum.

TREATMENT

Probably one does not yet know with certainty what is exactly the most suitable treatment. It is in fact difficult to assess the relative values of various treatments. In the series we now report, three cases were treated by Tavernier and five by one of us. The methods of treatment and the results are shown in Table II.

A similar diversity of treatment appears in the published observations of other authors. Most recommend surgical treatment. This consists essentially of removing the sequestrum from the head, with the expectation of results just as satisfactory as in the knee or in the elbow.

Unfortunately, in the hip, anatomical considerations are very special and the lesion is situated in the pressure area of the head of the femur. It may be that removal of the affected area allows fibrosis of the pressure zone with healing of the edges of the cavity. But that part of the surface of the head will remain irregular and deformed. This state of affairs seems to lead little by little to osteoarthritis. This is so true that the best of our cases seems to be the one in which the sequestrum was situated outside the pressure zone (Case 6, Fig. 10).

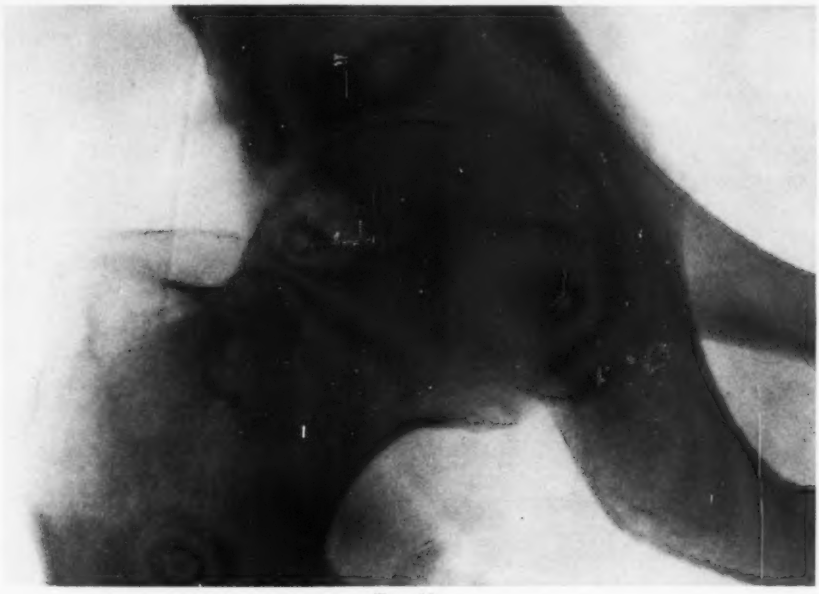

FIG. 11
Right coxalgia, presenting an appearance of capital sequestration suggesting osteochondritis dissecans.

FIG. 12
Epiphysial necrosis of caisson disease. (Radiograph belonging to Professor Roche, Medical Faculty of Lyon.)

Another factor that makes assessment difficult is that practically no long-term results are known. Most of the patients have not been observed for more than a few months; seldom have they been observed for more than two years, and observation for eight years is exceptional. Such a follow-up is too short to enable one to be sure that osteoarthritis does not occur, even if radiographically the contour of the head seems normal.

In these circumstances it seems that treatment may be considered along two lines. 1) In a patient less than fifteen years of age one may be tempted not to interfere directly, in the hope that spontaneous revascularisation of the sequestrum will occur. Our second case is in favour of such a course. But our first case, which was seen after eight years, and similarly that of Lange (1929), seen after the same time, have both resulted in osteoarthritis (Fig. 1). 2) In the adult surgical intervention has to be considered when disability is marked. Simple removal of the sequestrum has given good results in two of our cases, in two cases of Moulonguet (1932) after two and a half years and twenty months, in one case of Bergmann (1929) after eight months, in one case of King and Richards (1940) after two months and in another after an unspecified interval, and in two cases by Fontaine (1953) after fourteen months and nine months. But the average duration of follow-up was only about eleven months, and it must be remembered that there were failures (one of Moulonguet, our Case 3). Even in the cases in which the result was said to be good, many were not followed up for long enough. Other operations on the hip have little to recommend them. Our two arthroplasties were

TABLE II

ANALYSIS OF TREATMENT AND RESULTS (EIGHT CASES)

Nature of treatment	Number of cases	Result
Non-operative treatment		
Completely untreated . .	1	Follow-up insufficient (only four months)
Rest in plaster . . .	1	Eight years later subluxation and arthritis (treated by arthrodesis)
Operative treatment		
Simple exploration . . .	1	Good result after eight years
Removal of sequestrum . .	2	One was good a year later. One was fairly good six months later
Resection and remodelling of the head	1	Ten months later the hip was completely stiff
Arthroplasty (metal cup) . .	1	Hip mobile but painful on walking six months later
Arthroplasty (acrylic prosthesis)	1	Complete failure

failures, although possibly the conditions were not ideal. Even if there is a place for these operations in the old, there is certainly none in the young.

It seems to us, therefore, that the best thing to do is simply to remove the sequestrum. In doing this it must be remembered that, although the sequestrum appears obvious in the radiograph, it is necessary to dislocate the hip in order properly to see the lesion (Moulonguet, *loc. cit.*; King, *loc. cit.*). One has to realise that after removal of the sequestrum, the surface, as we have pointed out, will not be quite smooth and regular.

We think it might be a good idea, after removing the sequestrum and curetting its bed, to fill the cavity with a paste of cancellous bone. We tried this, probably a little imperfectly, in Case 7. It would moreover be necessary to cover this paste with finè cartilage grafts, which will probably survive well in the milieu provided by a joint (Moore 1948, Hirsch 1951). Alternatively one could cover the cancellous paste with a skin graft as practised by Kallio (1955).

In all these methods immobilisation in plaster would have to be employed for one month and weight bearing would not be allowed for three to five months.

SUMMARY

1. The pathological anatomy of osteochondritis dissecans of the hip is described, and its causation is discussed.
2. Eight new cases are reported.
3. The problems of treatment are considered.

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SUBLUXATION OF THE INFERIOR RADIO-ULNAR JOINT COMPLICATING FRACTURE OF THE RADIAL HEAD

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Subluxation or dislocation of the distal radio-ulnar joint has been regarded as one of the rarer complications after fracture of the head of the radius. Brockman (1930) and Essex-Lopresti (1950) each reported two cases, and Essex-Lopresti recalled that Murray (1940) had found no obvious wrist changes in 459 such fractures, Burton (1942) none in fifty, and Gaston, Smith and Baab (1949) none in 113 cases. Discussing Brockman's paper, Aitken (1930) recalled seeing a similar complication in one of his own patients who complained of weakness of the grip for a long time; Elmslie (1930) and Dunn (1930) differed as to whether the complication was important functionally or cosmetically. When Cherry (1953) advocated replacement of the fractured radial head with a prosthesis he asserted that this would prevent any tendency to upward displacement of the radius. There was considerable diversity of

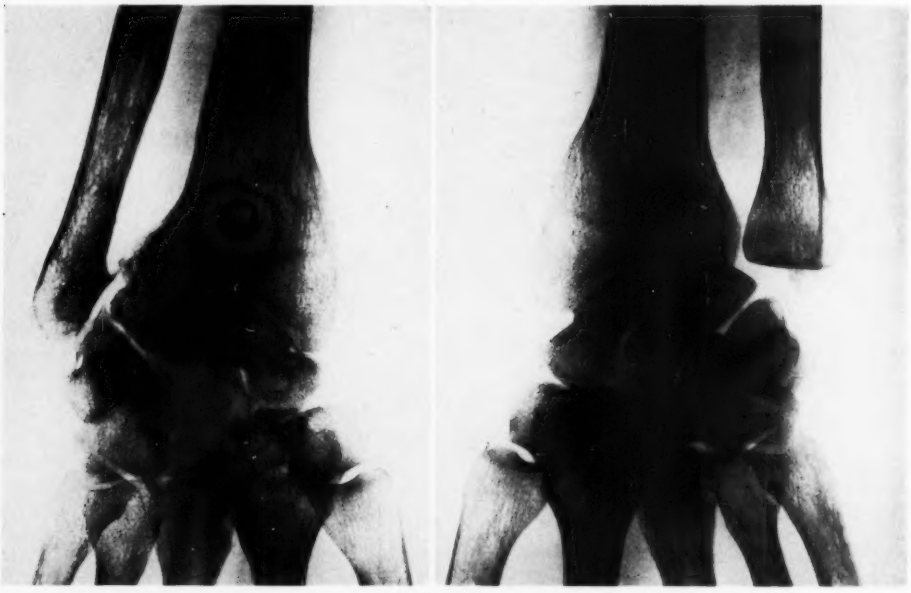

FIG. 1

Radiographs showing dislocation at the inferior radio-ulnar joint after excision of the radial head before cessation of growth. The normal wrist is shown for comparison.

opinion on this occasion, Jeffrey (1953) stating that he had examined a large series of patients who had had the radial head excised, and in none was he able to find evidence of subluxation. Watson-Jones (1953) believed that there was a place for the operation in the uncommon cases in which fracture of the radial head was associated with rupture of the interosseous membrane and marked upward displacement of the radius.

CLINICAL STUDY

During a review of 100 fractures of the head of the radius (Table I) a number of patients were seen who complained of pain and weakness of the wrist, and a closer study indicated that the complaints were referable to changes at the distal radio-ulnar joint. Accordingly the wrist joints of all in the series were carefully examined. Comparable radiographs of both wrists were obtained with every effort to prevent distortion, and it was possible to demonstrate displacement of the distal radio-ulnar joint due to an upward shift of the radius in twenty-five cases. The displacement varied from a minimal shift, only recognisable radiologically, to a subluxation or dislocation that was obvious clinically. Of the twenty-five patients five had severe displacement, six moderate and fourteen mild. All except one occurred after removal of the head of the radius.

TABLE I

CLINICAL DETAILS IN 100 FRACTURES OF THE HEAD OF THE RADIUS

	Total	Female	Male
Number of patients . .	94	41	53 (6 bilateral fractures)
Number of fractures . .	100	41	59
Treated conservatively . .	56	23	33
Head excised . . .	44	18	26
Upward displacement of radius	25	10	15
Severe	5	Nil	5
Moderate	6	1	5
Mild	14	9	5
Number with symptoms . .	12	3	9

CLASSIFICATION

From a study of the patients we reviewed we have classified distal radio-ulnar displacement associated with damage to the radial head into three main groups.

GROUP 1

Displacement consequent upon removal of the radial head before the cessation of growth. In children, removal of the radial head before growth at the epiphysis has ceased results in an upward shift of the radius. McFarland (1953) stated that he had not found a tendency for the radial shaft to migrate upwards, even when the radial head had been excised in children, but Fairbank (1930) quoted the case of a child who had had the head of the radius removed at the age of three, and at the age of twelve had two and a half inches shortening of the bone.

Case 1—A boy aged fourteen years had the head and part of the neck of the radius removed on account of an osteoclastoma. Ten years later the severe wrist changes confirm Fairbank's observation (Fig. 1).

It is an accepted principle that in the treatment of injuries to the head and neck of the radius in children the growing epiphysis should be preserved.

GROUP 2

Displacement recognised at the time of injury.

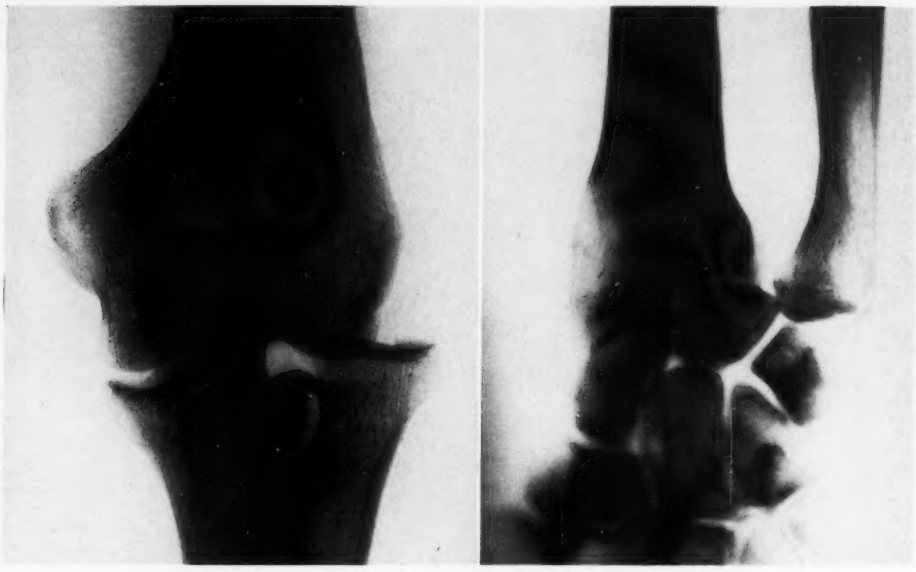

FIG. 2

Case 2—Fracture-dislocation of the head of the radius and dislocation of the inferior radio-ulnar joint occurring simultaneously at the time of injury.

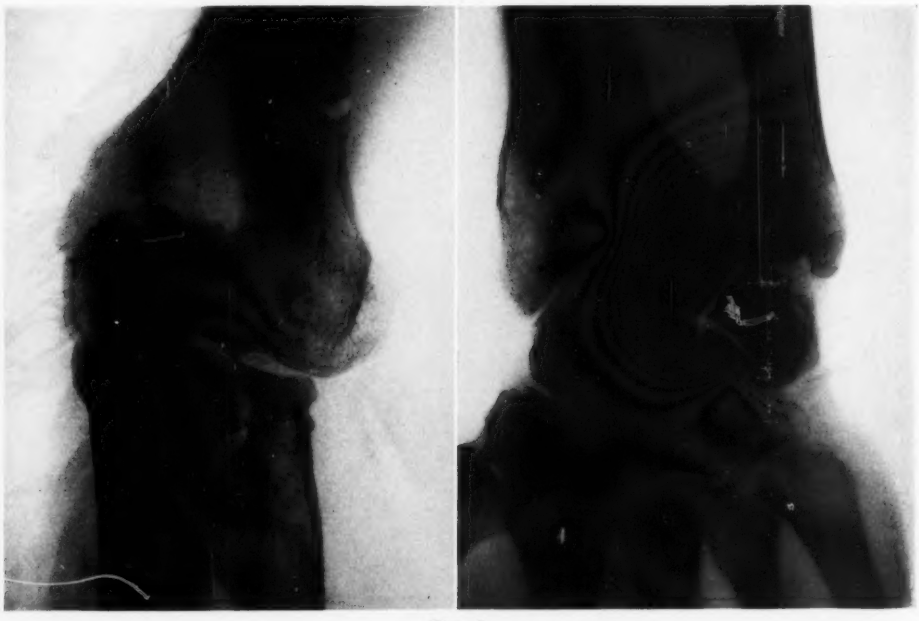

FIG. 3

Case 2—Radiographs taken five years later showing excised head and the degree of displacement at the wrist at that time.

Case 2—A farmer aged forty-seven was thrown forcibly from a motor-cycle and landed on his left hand. On admission to hospital he complained of pain at the elbow and wrist, and radiographs showed a fracture-dislocation of the radial head and subluxation of the inferior radio-ulnar joint, with upward displacement of the radius (Fig. 2). The displacement was corrected by manipulation, and a few days later the radial head was excised. Subsequent radiographs showed a recurrence of the subluxation at the wrist, but it was decided to accept the position. Five years later the displacement had increased, and osteoarthritic changes were present (Fig. 3). Elbow movement was from full flexion to 165 degrees extension; pronation was 50 degrees and supination 45 degrees. The patient's capacity for work was reduced, there was pain on heavy lifting, and the grip tested on a dynamometer registered 35 kilograms as compared with 90 kilograms on the normal side.

A similar case was published by Curr and Coe (1946), who up to that time could find no reference to such an injury in the literature. Failing to reduce the subluxation by manipulation they exposed the inferior radio-ulnar joint at operation, and found that the articular disc [triangular fibrocartilage] was badly torn and prevented reduction. A year later the patient had full flexion, lacked 30 degrees of extension, and had only 5 degrees of rotation. Essex-Lopresti recognised the upward displacement of the radius at the time of the injury in his second case, and in an effort to maintain reduction the head was reconstructed and not excised. Seven months later movement at the elbow was from 135 degrees to 60 degrees, and the total range of rotation was 45 degrees, but there were arthritic changes in the radio-humeral joint.

GROUP 3

Displacement after excision of the radial head. Subluxation of the distal joint may occur some time after removal of the radial head for fracture. Watson-Jones (1930) suggested that this was not infrequent because the radius was shortened, but he gave no figures of its incidence.

The displacement may be recognised soon after removal of the radial head, or several years may pass before it is noticed. The onset may be heralded by pain and swelling round the wrist, or it may be symptomless. The severity of the symptoms is not always related to the degree of displacement, but rather to the amount of use to which the wrist is subjected.

Case 3—A soldier aged twenty was thrown some distance in a bomb explosion and fell heavily on his right hand. He sustained a fracture of the radial head, which was excised. For a number of years after the operation he noticed an increasing prominence of the head of the ulna, but it was not until ten years after the injury that pain in the wrist made him seek advice. The inferior joint was subluxated (Figs. 4 and 5) but no arthritic changes were present.

Case 4—A concrete worker aged seventeen fell while playing football and injured his right elbow. He was found to have a fracture of the radial head with some displacement, and the radial head was excised. Nine years later the inferior radio-ulnar joint was found to be subluxated (Fig. 6). The function of the wrist had been excellent until a few months before, when he began to suffer pain. He was right handed, but the grip on the injured side registered only 30 kilograms as compared with 55 kilograms on the left side.

Case 5—Seven years after excision of the right radial head in a boy of eighteen years, a coach-builder, there was a distinct subluxation, but apart from some weakness of grip the wrist was symptomless (Fig. 7).

Case 6—A labourer was crushed by a concrete mixer in 1952 and sustained a fracture of the left radial head, which was excised. Four years later the inferior radio-ulnar joint was subluxated. Arthritis was present in both wrists, but more marked on the left side (Fig. 8).

Case 7—An airman aged nineteen had the head of the right radius removed after an injury. One year later he complained of pain and swelling of the wrist, and there was slight subluxation (Fig. 7). An enthusiastic tennis and badminton player, he finds his activities curtailed.

The examples quoted demonstrate the marked variability of the condition. All the cases with severe symptoms were in males; in females the displacement tended to be slight, and symptoms, if present, were confined to a feeling of weakness and pain after heavy work.

FIG. 4

FIG. 5

Case 3. Figure 4—Subluxation at the right distal radio-ulnar joint ten years after excision of the head of radius. Figure 5—Elbow showing amount of radial head resected.

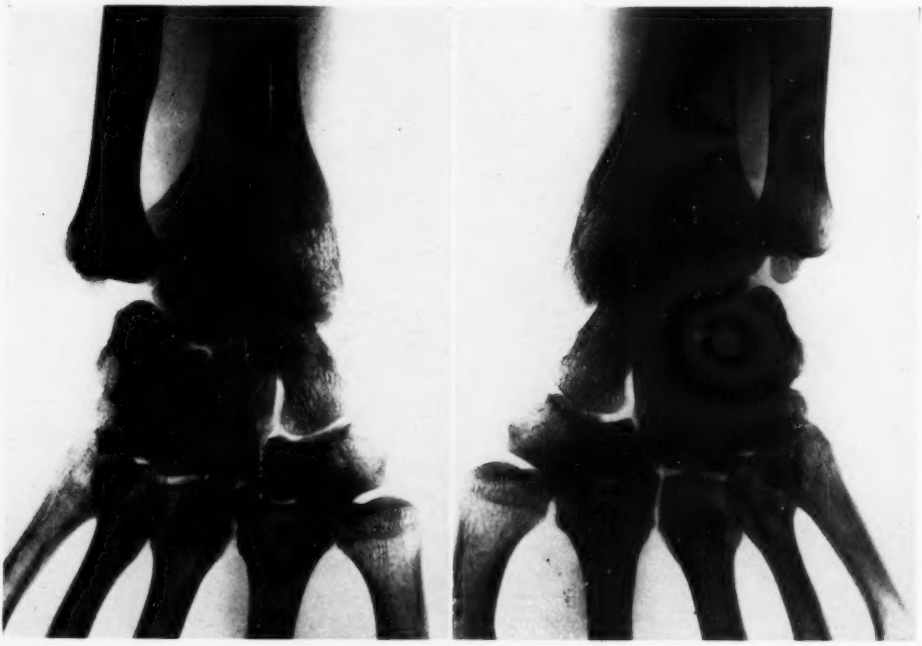

FIG. 6

Case 4—Dislocation at the right distal joint nine years after removal of the radial head for fracture. The normal wrist is shown for comparison.

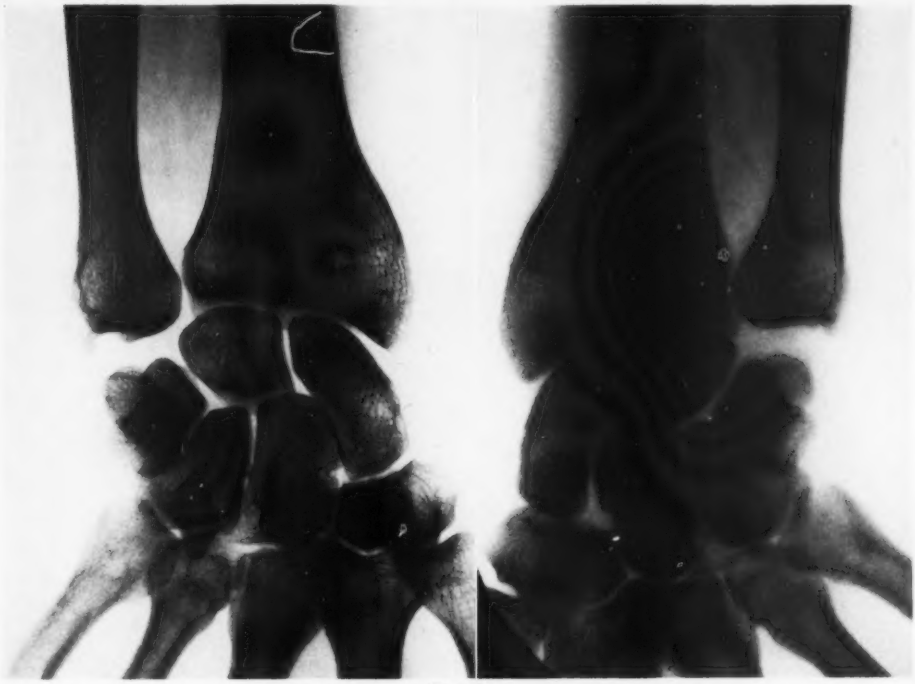

FIG. 7

Case 5—Dislocation seven years after excision of radial head. The normal wrist is shown for comparison.

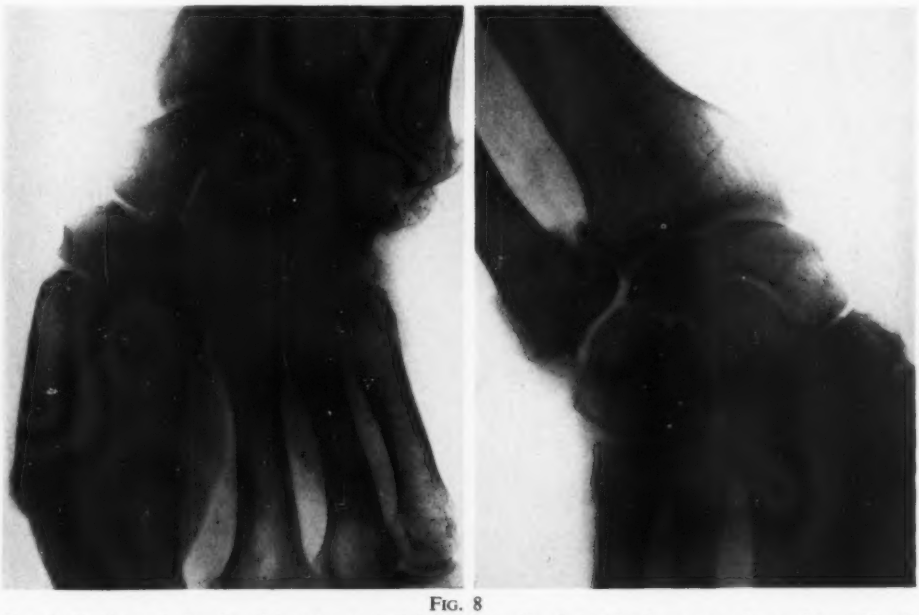

FIG. 8

Case 6—Radiograph showing dislocation at the left inferior radio-ulnar joint four years after excision of head of radius. Both wrists showed evidence of arthritis, but this was more marked in the left wrist.

FIG. 9
Case 7—Slight displacement, but with considerable disability, one year after excision of head of radius. The normal wrist is also shown.

DISCUSSION

Our figures are in strong contrast to those of the writers mentioned above who found no evidence of inferior radio-ulnar displacement in the cases they reviewed. In the few cases of displacement recorded, opinions differed on the mechanism of the displacement. Curr and Coe believed that the upward shift had been permitted by tearing of the interosseous membrane, but Essex-Lopresti found no evidence of damage to the membrane in his cases. In the one immediate upward shift in this series there was nothing to suggest that there had been tearing of the interosseous membrane on clinical examination, and subsequent radiographs showed no evidence of any bone changes that might have been expected if the membrane had been torn. When dislocation followed removal of the radial head a close study was made of the case histories and radiographs, but in none was there any evidence to suggest that the interosseous membrane had been torn.

Experimental displacements—In an effort to ascertain the mechanism of inferior radio-ulnar subluxation and dislocation, experiments were carried out in the post-mortem room.

After a radiograph had been taken of a normal wrist the head of the radius was removed. When firm pressure was applied to the radially deviated hand, radiographs showed a typical displacement of the inferior radio-ulnar joint, as found in the cases described above (Fig. 11). A small lever was next inserted into the elbow at the point where the neck of the radius had been divided, and pressure was applied in a distal direction. An equivalent downward shift of the radius at the wrist was demonstrable (Fig. 12). After division of the articular disc, firm pressure applied to the hand produced no increase in the displacement, and division of both disc and inferior joint capsule gave rise to no material increase in the subluxation.

FIG. 10

FIG. 11

FIG. 12

Experimental dislocations. Figure 10—Normal wrist. Figure 11—Upward shift of radius after removal of head and longitudinal compression. Figure 12—Distal shift after removal of head and downward pressure on neck.

Mechanism of displacement—The sacciform nature of the synovial membrane in both upper and lower radio-ulnar joints clearly allows for an up-and-down movement of the radius as well as the more commonly recognised rotatory movement, a fact pointed out by Thompson (1924) and demonstrated by Ogilvie (1930). "Pulled elbow" is an exaggeration of the downward movement in children. Up to the age of four years the head of the radius is not much larger than the neck, and when forcible traction is applied to the hand, the head slips down into the narrower part of the annular ligament which encircles it tightly, a fact that we have demonstrated in the post-mortem room. In the adult the head is much larger than the neck, and it can no longer be displaced downwards through the annular ligament.

The radius and ulna can be likened to two parallel struts fastened at the ends by the radio-ulnar joints, and in the centre by the interosseous membrane. Because of the direction of its fibres the interosseous membrane, when taut, can transmit to the ulna some of the pressure that is more directly exerted on the radius through the hand. That this is not the chief function of the membrane, however, is evident when one finds that it is not taut during pronation, which is the position most commonly assumed when pressure is transmitted from the hand (Frazer 1933). Upward migration of the bone is prevented by impact of the head of the radius against the capitulum, and when the stabilising influence of the head is lost after its removal the radius can move up until the slack in the interosseous membrane is taken up (Fig. 14), or the neck reaches the capitulum.

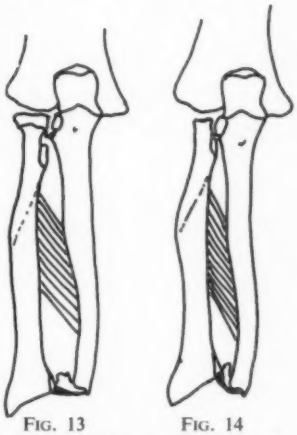

FIG. 13 FIG. 14

Diagrammatic representation of shift after removal of radial head. Figure 13—Normal state. Figure 14—Upward displacement of radius after removal of radial head; interosseous membrane intact.

In a further experiment we removed the head of the radius and divided the interosseous membrane but produced only the same degree of displacement as in the other experiments. It appears from these experiments that the interosseous membrane need not be torn to allow of the upward displacement of the radius.

Factors influencing the displacement—Displacement of the radius was not found in every case in which the radial head was excised; so certain factors must influence its occurrence. In our experiments we were able to produce varying degrees of displacement of the radius in different specimens; so we believe that there is a varying degree of tension in the interosseous membrane and the structures around the inferior radio-ulnar joint in different individuals. The amount of strain to which the forearm is subjected must play a considerable part, and we found the displacement most marked in men who were engaged in heavy manual work, or who were active in athletic pursuits that entailed the use of the hands. The natural action of the flexor and extensor muscles, and of the biceps, is to pull the radius proximally, and this is another factor that may account for the higher incidence of displacement in men. The amount of the head and neck resected must influence the degree and rapidity of the upward displacement, but we could find no evidence to suggest that repair of the annular ligament could have any material influence in preventing it, as has been stated by other writers.

The annular ligament is attached to the anterior and posterior margins of the lesser sigmoid cavity and forms a socket in which the head rotates. It is not directly attached to the radius, but is funnel shaped, and the narrower distal circumference slopes down and closes on the neck. When the head is removed, the controlling action of the ligament is lost, and it cannot prevent dislocation. In addition, there exists a degree of mobility of the upper radial shaft which is no longer held firmly against the lesser sigmoid notch, and when this increased movement occurs it is reflected in the relationship of the articular surfaces of radius and ulna at the wrist joint.

CONCLUSIONS

In this paper our object has been to try to correlate the many seeming anomalies that have appeared in the literature on this subject, and not to discuss the merits of removal of the head of the radius, or of its replacement by a prosthesis, an operation of which we have no experience. The conclusions we have reached are as follows.

If an injury is severe enough to disrupt both radio-ulnar joints and to dislocate the head of the radius, or to crush it severely, the upward shift of the radius occurs at the time of injury. If the injury is only severe enough to damage the radial head, and it is thereafter excised, any subsequent displacement is due to a gradual stretching of the articular disc and perhaps of the interosseous membrane, from pressure on the hand and muscle pull.

SUMMARY

1. Dislocation or sublaxation of the inferior radio-ulnar joint in association with fractures of the head of radius is discussed.
2. The incidence of the complication is greater than is generally supposed, and figures are given to support this finding.
3. The subluxation is not always associated with symptoms, and the degree of displacement may not be sufficient to be recognised clinically.
4. The anatomy and mechanism of the displacement have been investigated experimentally, and the results of the experiments are described.

We wish to thank Mr J. Patrick for permission to report these cases, and Professor T. Symington for the facilities he has afforded us in the Pathology Department. We are also indebted to Professor G. Wyburn of Glasgow University.

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RHEUMATOID ARTHRITIS PRESENTING AS TENOSYNOVITIS

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The etiology of tenosynovitis with effusion is often obscure, and this condition is frequently considered to be tuberculous. Vischer (1919), however, reported seven cases of tenosynovitis, all previously diagnosed as tuberculous, in which no evidence of tuberculosis was ultimately found; and Bickel, Kimbrough and Dahlin (1953), in a survey of sixty-three cases, found that fifty-two had been diagnosed as tuberculous, although conclusive evidence of tuberculosis was obtained in only thirty-seven cases.

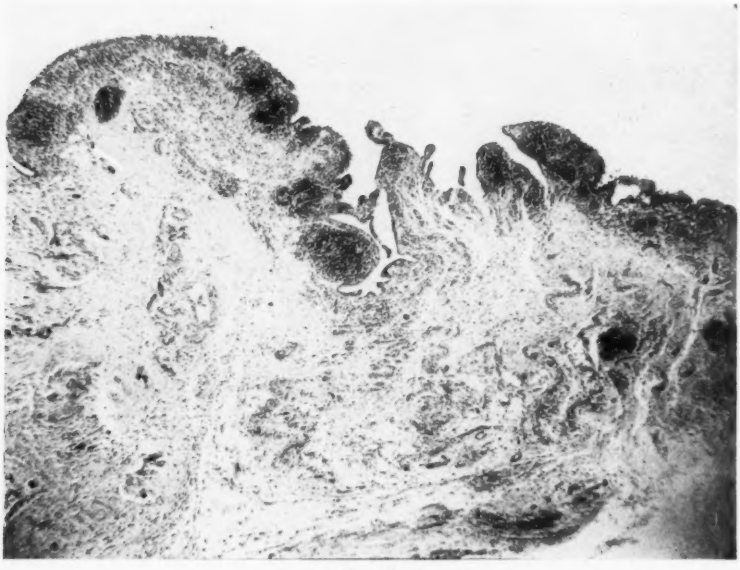

FIG. 1

Case 1—Tendon sheath showing chronic inflammation with focal lymphoid nodules and the formation of villous folds. (H. and E., ×50.)

It is well known that tendons and tendon sheaths may be involved in the course of rheumatoid arthritis and that this involvement may take the form of nodular tendinitis or of tenosynovitis. It is, however, not so widely recognised that early rheumatoid arthritis may present as isolated attacks of tenosynovitis, and that histological examination of the affected tissues is necessary to establish the diagnosis at this stage. Three cases are reported in which tenosynovitis of the hands and wrists was the primary manifestation of rheumatoid arthritis.

Case 1—A woman aged forty-one years complained of a swelling which had been present for five months on the back of the right hand. Examination revealed a lobulated, painless, fluctuant mass in the region of the extensor tendons, and there was also a small mass on the flexor aspect of the left middle finger. A radiograph of the chest was normal and the erythrocyte sedimentation rate was 9 millimetres in one hour.

The extensor tendon swelling was explored surgically eight months later. The tendon

sheath, which contained an ounce of thick mucinous fluid, was found to be grossly thickened and to have a pink and ragged lining.

Microscopically the tendon sheath was swollen and hyperaemic. Numerous villi, of

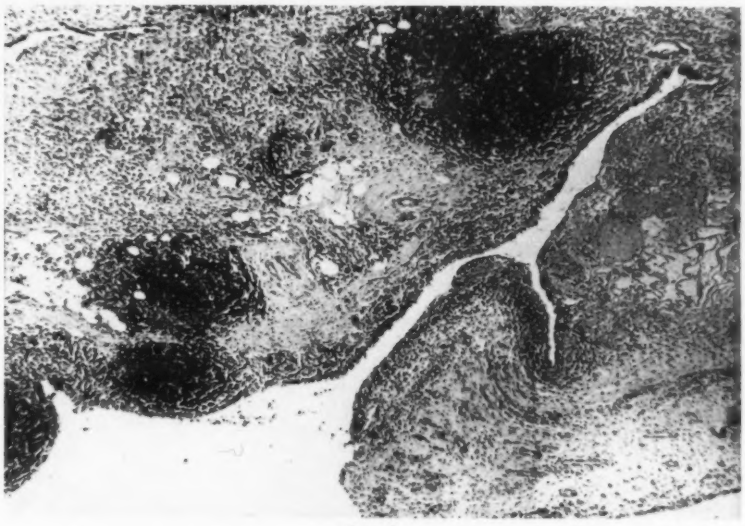

FIG. 2

Case 1—Tendon sheath showing parts of two synovial villi. Fibrinous exudate is present in the tissues (right) as well as large lymphoid nodules. (H. and E., ×100.)

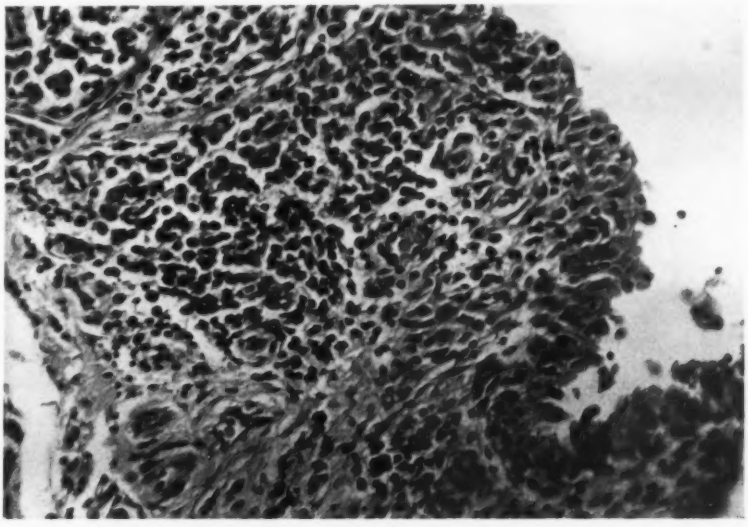

FIG. 3

Case 1—A synovial villus covered with proliferating synovial cells and showing a dense plasma cell and lymphocytic infiltration. (H. and E., ×300.)

varying sizes and shapes, projected from the synovial surface, much of which was covered by a thick, irregular layer of proliferating synovial cells. In places fibrinous exudate was present on the surface, and here and there fibrin was being incorporated within the wall of

the tendon sheath by an overgrowth of the proliferating synovial cells. The subsynovial tissue contained many lymphoid nodules, some with germinal centres; these were largest and most numerous near the synovial surface. In addition, the villi showed diffuse infiltration with lymphocytes and plasma cells (Figs. 1 to 3).

The patient remained well for two years when she complained of a painful right wrist, elbow, left middle finger and left knee. There was swelling, with limitation of movement, of the proximal interphalangeal joint of the left middle finger and of the right wrist, and there was an effusion into the left knee joint. The erythrocyte sedimentation rate was 38 millimetres in one hour, and radiographs of the hands showed narrowing of the left third proximal interphalangeal joint space, with a small juxtacapsular erosion. A diagnosis of rheumatoid arthritis was made.

Case 2—A woman aged forty-two years complained of a painful swelling which had been present for two months over the palmar aspect of the right thumb. There were fluctuant swellings over the flexor aspects of the thumb and middle finger, with limitation of movement. Radiographs of the hands and chest were normal and the erythrocyte sedimentation rate was 30 millimetres in one hour.

The tendon sheath of the thumb was explored surgically and found to be swollen and tense. The patient remained well for six months when she developed a diffuse painful fluctuant swelling over the back of the left wrist. There was no change in the radiographic appearance of the hands or in the sedimentation rate.

A second operation was performed a year after the first. The extensor tendons were found to be surrounded by filmy granulation tissue, which extended up into the grooves under the extensor retinaculum [dorsal carpal ligament].

Microscopically, the tissues removed at the two operations were similar. There were oedema and increased vascularity of the tendon sheaths, with the formation of many synovial villi covered with proliferating synovial cells. Near the synovial surface the tissues were diffusely infiltrated with plasma cells, and in addition there were nodular collections of lymphocytes. Lymphoid nodules were also present in smaller numbers in the deeper parts of the sheath. In some areas the synovial surface was covered by fibrin (Figs. 4 and 5).

The patient remained well for a further six months when she complained of pain in the right index finger. Radiographs revealed a small erosion on the inner side of the head of the proximal phalanx. Within another six months there was involvement of the proximal interphalangeal and metacarpo-phalangeal joints of the left ring finger.

The erythrocyte sedimentation rate was 63 millimetres in one hour and radiographs showed the changes typical of rheumatoid arthritis in both hands.

Case 3—A woman aged sixty-eight years complained of stiffness in the fingers and thumb of the right hand. Radiographs of the hands were normal, as was the erythrocyte sedimentation rate. A diagnosis of " carpal tunnel syndrome " was made, and at operation the median nerve was seen to be flattened and to be bulging forward at the proximal end of the flexor retinaculum, which was divided. Three months later she complained of persistent pain and recent swelling on the flexor aspect of the right ring finger. A diagnosis of tenosynovitis was made. At operative exploration multiple adhesions and a collection of viscid fluid were found between the flexor tendon sheath and the tendon.

After a further three months the patient complained of pain in her shoulders, hands and feet. The proximal interphalangeal and metacarpo-phalangeal joints of the left hand, and the proximal interphalangeal joint of the right index finger, were found to be swollen and tender, and there was tenderness over the heads of the metatarsals of the left foot. She was admitted to hospital, and radiographs showed evidence of rheumatoid arthritis in the hands and feet. The erythrocyte sedimentation rate was 10 millimetres in one hour, and the euglobulin Rose test was positive.

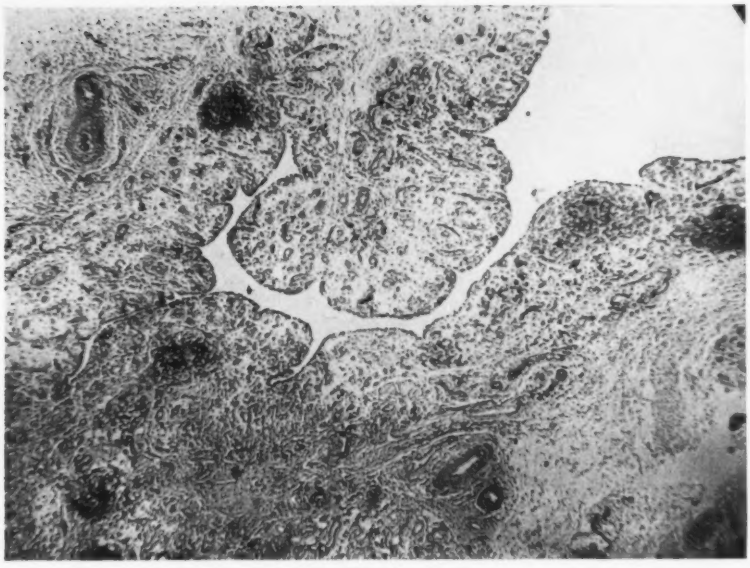

FIG. 4
Case 2—Tendon sheath showing oedema and congestion of synovial folds. Several lymphoid nodules are present. (H. and E., ×100.)

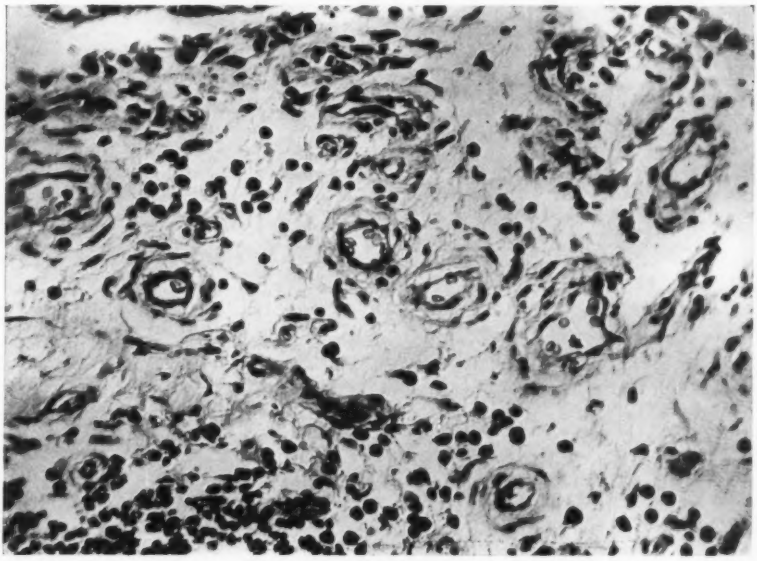

FIG. 5
Case 2—Oedema and increased vascularity of subsynovial tissue, with diffuse plasma cell infiltration. (H. and E., ×300.)

DISCUSSION

In the three cases of rheumatoid arthritis reported, involvement of the joints first became apparent eighteen months, fourteen months and four months, respectively, after the preceding attacks of tenosynovitis. One of these patients (Case 2) had two attacks of tenosynovitis, one affecting the right hand and the other the left, before the development of arthritis. These two attacks were separated by an interval of eight months.

It is often impossible to distinguish, on clinical grounds, between tuberculous tenosynovitis and isolated rheumatoid tenosynovitis. The appearance of the tendons and sheaths at operative exploration may still leave the diagnosis in doubt, and it is not until the tendon sheaths have been examined histologically that the true nature of the condition becomes apparent.

Kellgren and Ball (1950) gave a detailed account of the pathology of the tendons in rheumatoid arthritis, and they mentioned briefly the changes in the tendon sheaths. Their findings agree with ours, except that they describe areas of " fibrinoid necrosis " which were not seen in our cases. Our material did, however, show the formation of fibrinous exudate upon the synovial surfaces; this became covered by synovial lining cells and was eventually incorporated into the substance of the tendon sheaths. Bywaters (1949), discussing the changes in synovial membranes in rheumatoid arthritis and in other conditions, stated that fibrin deposited upon synovial surfaces may later be incorporated in the synovial membrane.

The three biopsies taken from our cases showed hyperaemia and oedema of the tendon sheaths, proliferation of synovial lining cells with exudation of fibrin upon synovial surfaces, and diffuse infiltration of the tissues with lymphocytes and plasma cells, together with the formation of circumscribed lymphoid nodules.

Hyperplastic tenosynovitis, with lymphoid infiltration, like that seen in the joints, may occur in rheumatoid arthritis (Collins 1949). This author stressed the importance of " focal aggregations of lymphoid cells " as a diagnostic, though not pathognomonic, feature of this disease. While no single one of the changes seen in the tendon sheaths in our cases can, by itself, be considered specific of rheumatoid arthritis, collectively they provide strong presumptive evidence of that diagnosis.

Since rheumatoid arthritis is now generally recognised to be a systemic disease affecting mesenchymal tissues, it is not surprising that at times the tendon sheaths may be involved before any articular or other manifestations become evident.

SUMMARY

1. Three cases of tenosynovitis presenting as the first manifestation of rheumatoid arthritis are described.
2. An account is given of the histology of the affected tendon sheaths.

We are grateful to Mr Charles Gray and Dr E. T. D. Fletcher for permission to publish these cases. Our special thanks are due to Dr G. B. D. Scott for his advice, to Miss Kathleen Page for histological preparations, and to Mr J. S. Sheppard for photographic illustrations.

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DYSPLASIA EPIPHYSIALIS PUNCTATA

Report of a Case with Discussion

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Dysplasia epiphysialis punctata is a rare congenital disorder of infancy affecting in particular cartilage, muscles and joint capsules, and the eyes. It is associated with obvious growth defects in patients surviving long enough to show them. The severity varies in the different cases reported. In the present case the distribution was widespread, with generalised changes complying with the clinical and pathological picture now considered characteristic of the condition.

This report was in preparation when Frank and Denny (1954) described a similar case. Ours is therefore offered as yet another case, presenting certain additional features, mainly of degree, and a strong parental luetic history, with a radiological and histological study.

Previous literature has been reviewed by Mosekilde (1952) and others. The first case was described by Conradi (1914) as supposedly an abortive form of achondroplasia or chondrodystrophy. The first American report, by Tisdall and Erb (1924), described " calcareous deposits in joints "; the child died early and a patent ductus arteriosus was found. About fifty cases have since been described under many different names. In America the term "chondrodystrophia calcificans congenita" is favoured, whereas dysplasia epiphysialis punctata or stippled epiphysis, suggested by Fairbank (1951) and Weber (1936), is preferred by others.

The etiology is still unknown. Many different suggestions, based mostly upon what seems to be a coincidence, have included: syphilis (Tisdall and Erb 1924), hypothyroidism (Reilly and Smyth 1938) and a developmental anomaly (Maitland 1939). Mosekilde (1952) suggested a disturbance of calcium metabolism in mother and child.

In the case described below there was a strong luetic infection in the family without sign in the patient.

Raap (1943) published four cases in which he investigated the whole family including the father, mother and two grandmothers. All were healthy. There is no evidence of heredity, but the disease seems to be familial, as in Raap's five patients, all belonging to the same family: twins ten months old, one newborn baby and an older child two and a half years of age. All three youngest children showed typical changes of dysplasia epiphysialis punctata; the other one showed a normal skeleton except for a few densities in the bones of wrists and ankles which suggest that she may have had the characteristic changes previously. Most of the patients described were infants, and most have died in their first year. Fairbank's (1951) inability to find any later report of a case showing generalised changes may be explained by Raap's investigation, in which he followed his cases for four years and showed that the abnormal calcifications apparently are marked at birth but disappear by the age of about three years. Haynes and Wangner (1951) also stated that the stippling heals and becomes uniform in time. Selakovich and Warren White (1955) have reported the late effects at the age of twelve years: shortening of the entire extremity with smallness and abnormality of the bones. Serial radiographs showed a progression from the stippling stage into complete calcification, ossification and healing, indicating a definite chondrodysplasia.

The disorder does not affect the epiphyses alone, but even the soft tissues of the locomotor system and in many cases the eyes. Mosekilde (1952) has listed the following five signs which are so often encountered as to constitute a typical picture or diagnosis: 1) micromegalia and

rhizomelia; 2) additional shortening of one to four centimetres in one or possibly two extremities; 3) semiflexion and limitation of extension of larger joints; 4) bilateral congenital cataract; 5) stippled epiphyses.

In addition some of the following deformities will often be found: congenital heart disorder, short neck, enlarged fontanelles, retracted bridge of nose or broad and flat nose, adactyly, hypodactyly, syndactyly, varus or valgus deformities of the hip, knee and ankle, luxations, notably of the hips, and ulnar deviation of the wrists. In some cases skin lesions are found, such as exfoliative dermatitis, follicular atrophodermia, and ichthyosis sebacea.

Complete blood chemistry investigations including estimations of the calcium, phosphorus, cholesterol and phosphatase have yielded normal results with few exceptions.

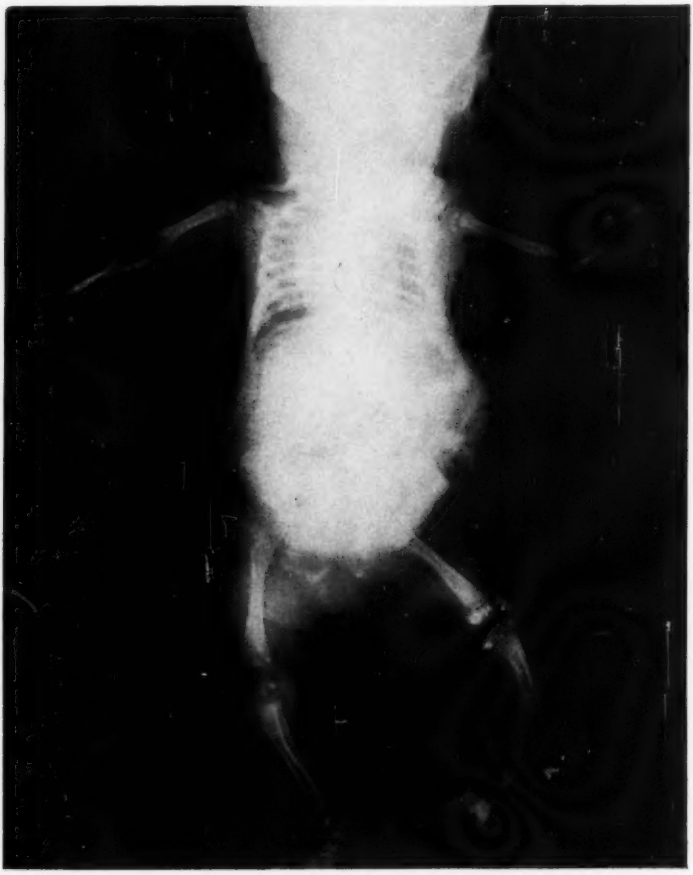

FIG. 1

Radiograph showing stippling of epiphyses generally. Localised bulging of the abdominal wall with gas in the bowel. Contractures of left lower extremity seen.

CASE REPORT

A Chinese girl, one month old, was brought to hospital on account of deformities of the arms and legs.

History—The father had syphilis in 1942. He was treated for several years, receiving eighty

intramuscular injections (probably of bismuth or arsenic). At the time of his infection he already had four children. The fourth child died when a few months old. All the other three daughters were healthy and strong. The mother's fifth and sixth pregnancies ended in abortion at about the twentieth week. The child of the seventh pregnancy had sores on her head at birth. The mother's blood gave a positive Kahn reaction. She was given a course of sixty intramuscular injections and the child ten. The next child (eighth pregnancy) was born healthy but the mother had another course of ten injections; the child was said not to need treatment. With the pregnancy (ninth) of the present child the mother had a course of twenty injections. There was no remembered injury during pregnancy. A breech presentation was followed by an uneventful delivery.

FIG. 2
Stippling of the left patella and of the epiphyses of the left knee.

FIG. 3
Stippling of the epiphyses in right leg. Note the extensive stippling in the tarsal bones.

Examination—The child appeared somewhat dwarfed, with shortening of the neck. There was marked contracture of the left hip and knee, the right elbow, and the left foot, which was kept in the equinovarus position. The left lower leg showed bowing of 10–15 degrees and there was half a centimetre of real shortening of the left leg. The left hip had a flexion contracture of 60 degrees with 45 degrees of abduction, and joint movements were greatly restricted. There was a 45 degrees' flexion contracture of the left knee, which could be forced to 10 degrees short of full extension. The right elbow showed a limited extension of 45 degrees. The eyes showed cataract, worse in the left. A serological test for syphilis was negative.
Radiography revealed a widespread disturbance of ossification. The affected epiphyses were stippled, calcium being deposited in small spots much denser than normal bone. Most of the deposits were discrete, with well defined outlines, rounded or comma-shaped. Some

coalesced and showed marked irregularity in size, shape and density. Stippled deposits were visible at the proximal ends of the humerus, radius, ulna, femur, tibia and fibula on both sides. All the vertebrae, including the sacral segments, were involved, and some deposits were visible in the coccygeal region. In the scapulae deposits were present in the acromion processes and near the inferior angles. In the pelvis (Fig. 1) there were deposits near both iliac crests, in the acetabular regions, in the pubic and ischial rami, and in the ischial tuberosities. Both patellae (Fig. 2) were affected. In the thoracic region scattered stippling was visible, probably in the costal cartilages. Extensive stippling was present in the carpal regions (Fig. 4), and the individual bones were indistinguishable. In the metacarpal regions a few dense spots were present; these may have been due to overlapping shadows, the

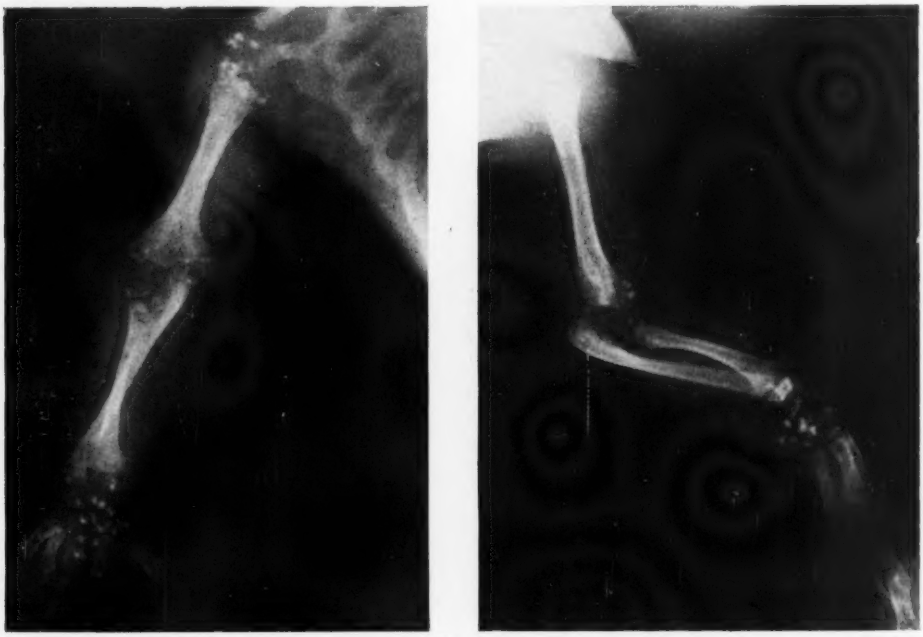

FIG. 4
Both arms, showing stippling in shoulder, elbow and wrist.

metacarpal bones being probably unaffected. The phalanges appeared normal. In the feet the calcaneum and talus were outlined on both sides by aggregations of dense deposits (Fig. 3). The other tarsal bones also were affected but their outlines were ill defined. Apart from a few spots probably caused by overlapping shadows the metatarsal bones and phalanges appeared unaffected. The clavicles and cranial bones appeared normal. The diaphysis of the left tibia had a varus curvature and seemed to be slightly shorter and broader than its fellow. The diaphyses of some of the other long bones might be slightly broader than normal at their ends, but otherwise were well formed and normally ossified.

Post-mortem examination—Three days after the child was first seen she died of bronchopneumonia, verified at routine necropsy. The body was buried but exhumed the next day, and parts of the tibia, lumbar vertebrae, calcaneum, femur and ilium were removed for further study.

In radiographs made after death the cartilaginous epiphyses at the shoulder, elbows, hips and knees were faintly outlined in contrast to gas in the soft tissues. With the exception of the right femoral epiphysis they appeared to be normally formed. At the elbows and knees the stippled deposits occurred near the metaphyses and most of the cartilage was uncalcified. At the shoulders and hips deposition was mainly at the lower borders of the capital epiphyses and in the regions of the greater tuberosities and trochanters. The right femoral capital cartilage appeared to be smaller than normal and flattened. It appeared to be dislocated, but this may have been a post-mortem effect.

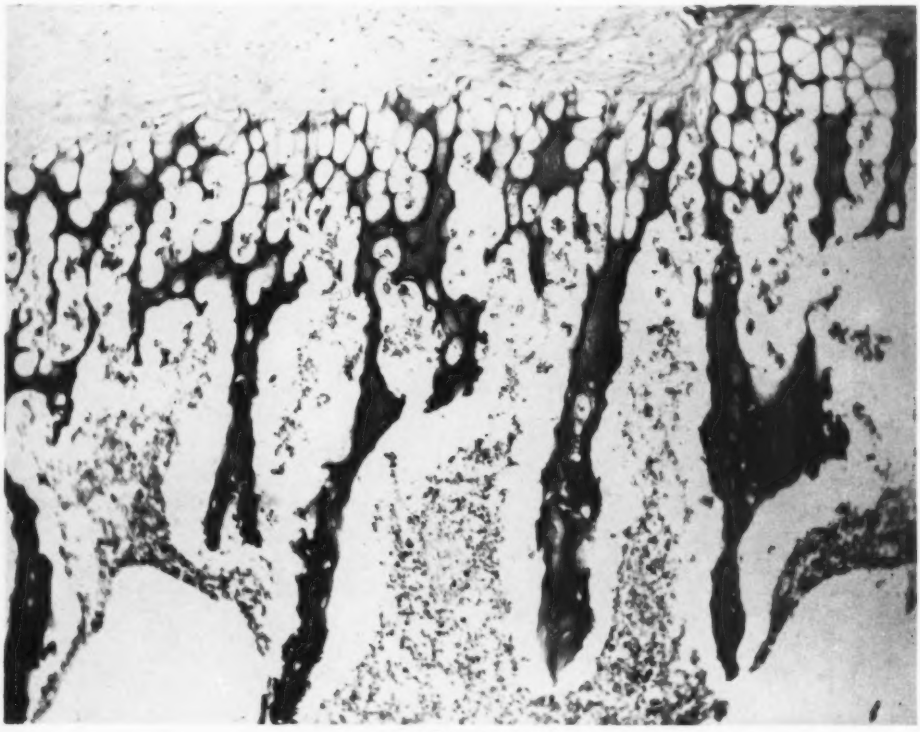

FIG. 5
Lower end of femur, showing the reasonably normal endochondral ossification occurring in this situation. (×120.)

Histological examination—The material consisted of sections from the lower end of the femur and from other unspecified epiphysial cartilage. Cortical bone, where present, was thin but did not show any other significant histological abnormality. The region of endochondral ossification at the lower end of the femur (Fig. 5) appeared normal. The important histological abnormality was the presence, throughout the tissue of the epiphysial cartilages studied, of abnormal circumscribed areas reaching one or two millimetres in size (Figs. 6 to 9). These areas contrasted with the surrounding cartilage in staining darkly and irregularly, and they were presumed to indicate sites of calcification. Some of them showed proliferation of cartilage cells, whereas others showed advanced degeneration of the tissue with complete loss of cells. Occasional areas of vascularisation of the degenerated calcified cartilage and of localised bony replacement of the tissue were seen, but they were not a conspicuous feature.

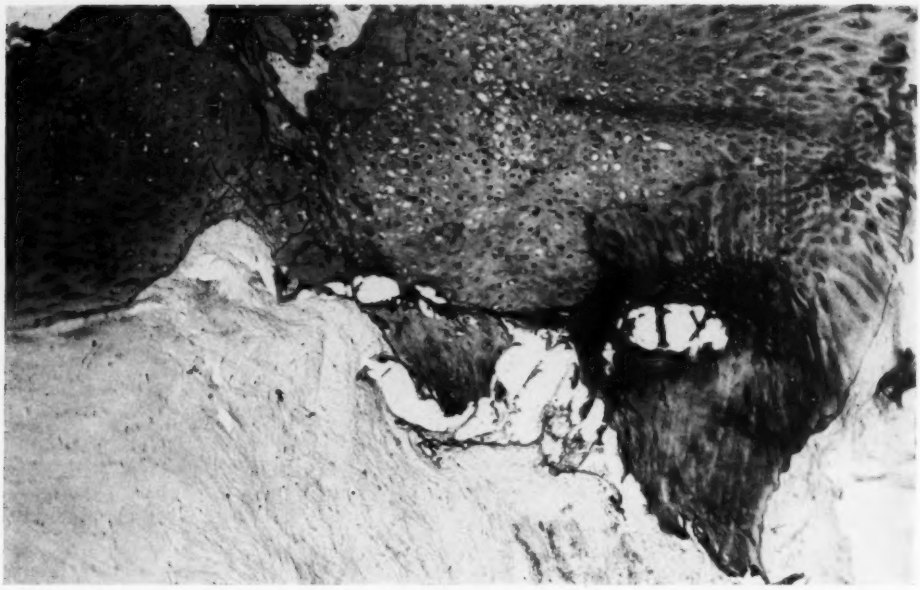

FIG. 6

Lower end of femur. Part of a focal area of calcification in the cartilaginous epiphysis. The pale-staining uncalcified cartilage of the epiphysis in the lower part of the field has undergone a considerable amount of post-mortem autolysis. Note the separation that has occurred at the margin between the calcified and uncalcified tissues. (×120.)

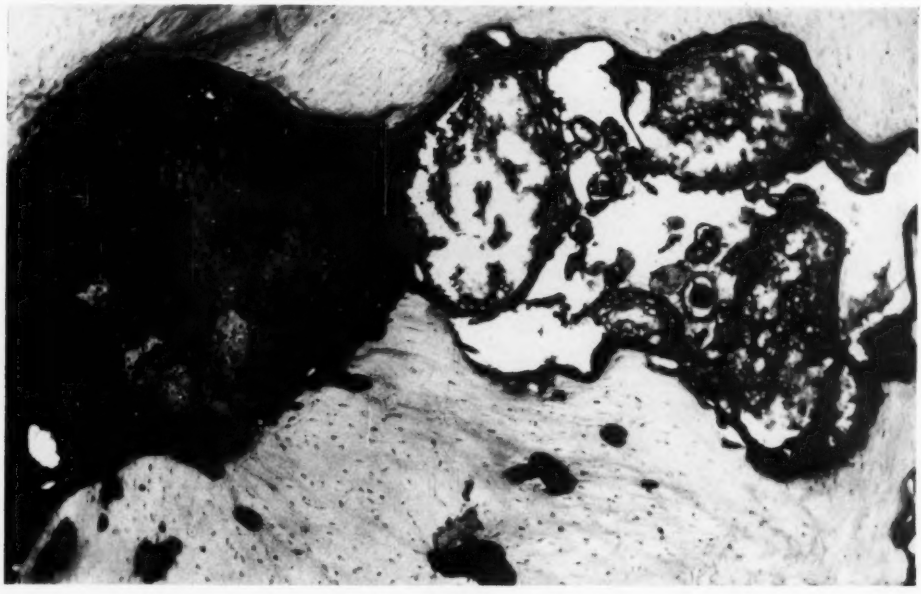

FIG. 7

Epiphysial cartilage from unspecified site. Large and small areas of focal calcification in the epiphysial cartilage. The large area on the left of the field shows cellular proliferation of the darkly staining (and hence presumably calcified) cartilage. That on the right, however, while staining darkly shows advanced degeneration. (×120.)

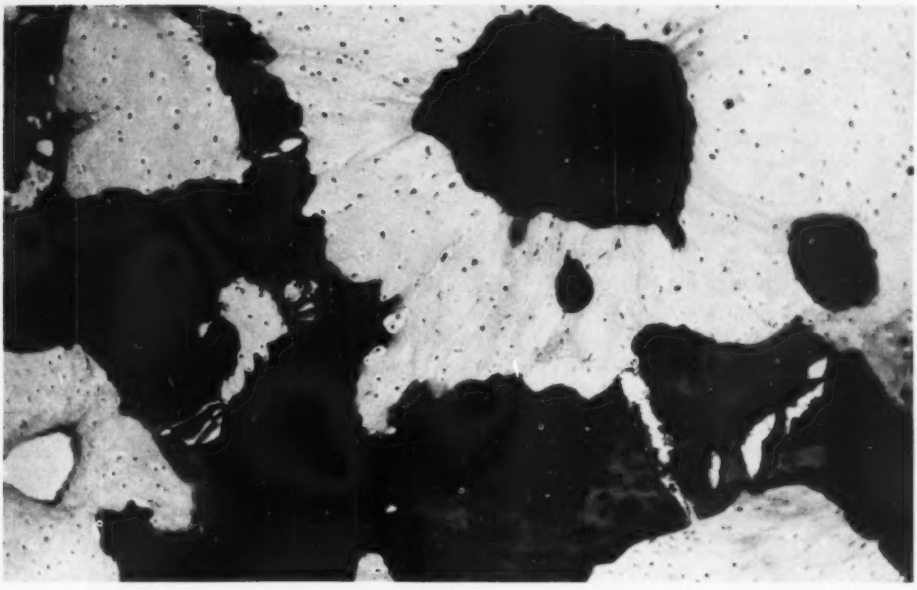

FIG. 8

Epiphysial cartilage from unspecified site. Areas of focal calcification. Note the area of "cystic" degenerative change in the uncalcified cartilage towards the lower left corner of the field. (×120.)

FIG. 9

Epiphysial cartilage from unspecified site. Area of focal calcification. Although considerable post-mortem autolysis was present, this focus showed evidence of vascularisation and bony replacement of cartilage in the neighbourhood of the area of degeneration in the lower part of the field. (×120.)

The uncalcified epiphysial cartilage showed occasional small areas of cystic and fibrous degeneration. Very pronounced post-mortem autolysis appeared to be present, and it was of interest (Fawns and Landells 1953) that this had involved the uncalcified epiphysial cartilage far more than the focal areas of calcified tissue. The autolysis prevented accurate assessment of the extent of histological change in the uncalcified tissues.

DISCUSSION

There is still so much to be learned about the etiology of the dysplasias and dystrophies that it is important to obtain as much information as possible from each case that is reported.

We already have enough facts about this case to make a diagnosis of dysplasia epiphysialis punctata and to exclude other conditions presenting epiphysial stippling, such as cretinism and dysplasia epiphysialis multiplex.

The widespread generalised distribution of the lesion might suggest an avascular necrosis, with subsequent revascularisation and regeneration (Haynes and Wangner 1951). That both parents in this case suffered from syphilis might have been coincidental; yet it cannot be disproved that the foetal cartilage may have degenerated, fragmented and calcified as a result either of the syphilis or of the treatment by arsenic or bismuth which had interfered with the primitive vascular supply to the epiphyses. On the other hand the presence of associated anomalies, such as flexion contractures of the limbs and early retardation of growth as seen also in achondroplasia, could be explained by the interference of some factor toxic or infective, in the early embryo stage as shown by Duraiswami (1952) using insulin in the chick embryo.

The widespread skeletal involvement suggests a severe lesion and is often accompanied by early death, but the cases of Raap (1943) and of Selakovich and White (1955) show that the punctate areas of calcification do reabsorb and regenerate by the age of twelve, leaving only shortening of the extremity with smallness and abnormality of the bones. The calcified foci are clearly distinct from ossification centres. (Ossification centres appear later and are not involved in the process.)

Harris (1933) found, as in achondroplasia, patchy mucoid degeneration and cystic spaces preceding calcification in the cartilaginous epiphyses; this degeneration is also noticeable in the present case.

It seems worth while making a further suggestion as to the etiology of this rare condition in the hope of stimulating further investigation. Is it not likely that the vessels supplying the growing epiphyses and metaphyses, or the cells themselves of these parts, are damaged at different ages by some toxic or infective factor confining the lesion to the epiphyses in dysplasia epiphysialis punctata or to the metaphyses in metaphysial dysostosis (case reported by Cameron, Young and Sissons 1954)?

SUMMARY

1. A case of dysplasia epiphysialis punctata is described, with some histological observations.
2. Both parents were syphilitic.
3. The etiology is not yet fully determined. Some suggestions are put forward for further investigation.

We are indebted to Dr H. A. Sissons, Department of Pathology, Institute of Orthopaedics, University of London, for the histological report, photomicrographs and assistance in the preparation of this report; to the Radiological Department, General Hospital, Singapore, for assistance in obtaining radiographs; and to the Director of Medical Services, Singapore, for permission to publish this report.

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FATIGUE FRACTURES OF THE LOWER TIBIA AND FIBULA IN THE SAME LEG

Report of a Case

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From the Royal Infirmary, Falkirk

Since attention was focused on the subject by Burrows (1940) many fatigue fractures of the lower fibula have been reported. Fatigue fractures of the lower tibia, however, are uncommon. Singer and Maudsley (1954), describing five cases, could find only three previous examples in the literature. I can find no record of fatigue fractures affecting the lower thirds of the tibia and the fibula of the same limb at the same time.

CASE REPORT

A boy of sixteen years complained of pain over the outer side of the right ankle when he attempted to run. He had no discomfort when walking. When he was first seen the symptoms had already been present for five months. The pain was noticed first during a six-mile road run. Running was one of his main recreations and he usually went for a long run once a week. On this particular occasion he developed a pain in the region of the right ankle after running about three miles. He was unable to finish the course and walked home. The ankle became stiff and painful but after a day in bed and the application of strapping to the leg he was able to get about in relative comfort. A week later he resumed his usual activities but the pain recurred whenever he tried to run or even stand on tip-toe. There was no history of injury.

On examination the patient was tall and thin. There were thickening and tenderness in the region of the lowest third of the right fibula. The skin temperature was normal and there was no oedema. Ankle and tarsal movements were free and painless, but when asked to stand on tip-toe he complained of pain over the lower third of the fibula.

Radiographs showed an old fracture of the lowest third of the right fibula two inches from the tip of the lateral malleolus (Fig. 1). There was expansion at the fracture site with a gap between the bone ends. The distal fracture line was concave and showed some sclerosis. There was rarefaction proximal to the fracture, with scattered calcification between the fragments.

Progress—The nature of the fracture was not clear at the time, and it was decided to put the leg in a below-knee walking plaster for a month and observe the progress of the lesion. It was thought that this was probably a fatigue fracture showing unusual indolence in uniting, but the possibility of its being a fracture through a chondroma or some such lesion was borne in mind. The plaster was removed after four weeks. The tenderness had disappeared from the lower fibula but now there were thickening and tenderness over the subcutaneous surface of the lowest third of the tibia. Radiographs revealed the presence of a transverse fracture of the lower tibia three and a half inches above the medial malleolus (Fig. 2). The fracture line was faint but there was unmistakable infraction of the lateral cortex. A faint band of sclerosis ran across the bone, and subperiosteal calcification extended up and down the medial cortex for about two inches. Re-examination of the previous films with a lens failed to show any abnormality in the tibia. On direct questioning the boy admitted that, after wearing the short plaster for two weeks, he had noticed discomfort in the lower part of the leg, especially when he turned sharply to either side.

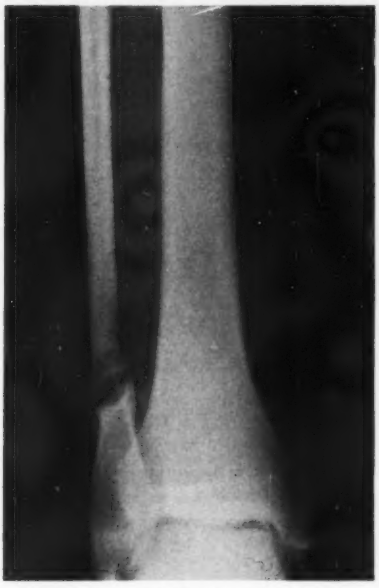

FIG. 1

FIG. 2

Figure 1—Initial radiograph. Fatigue fracture of lower fibula. Tibia apparently normal.
Figure 2—One month later. Fatigue fracture of the lower tibia.

FIG. 3

FIG. 4

Figure 3—Six months later. Note how the infraction on the lateral aspect of the tibia resembles the original fibular lesion. On the medial aspect the tibial fracture is consolidating. The fibula is slowly uniting. Figure 4—A year after first examination. Solid union of the tibia but with slight valgus angulation. The fibular fracture is united but not yet completely consolidated.

Treatment—A toe-to-groin walking plaster was applied and worn for two months. After its removal radiographs showed satisfactory progress in both the tibial and fibular fractures. Strapping was applied and a week later he stated that his leg was comfortable. He was kept under close observation and his activities were restricted. The thickening over the tibial fracture was now quite marked and tenderness was still present.

Further progress—Six months after his first attendance he reported discomfort over the lower tibia which gradually increased till he was unable to climb stairs without pain in the whole of the right leg. Tenderness had increased also and the skin over the fracture was warmer than normal. Radiographs showed that although there was satisfactory buttressing on the medial side of the tibial fracture the infraction on the lateral side had increased till it closely resembled the original fibular fracture, which was by now slowly uniting (Fig. 3). Because of his discomfort a second long-leg plaster was applied. This was kept on for a further two months. When it was removed the local signs of swelling over the tibia were found to have subsided. There was no tenderness over either fracture. Six weeks later he was symptomless. A year after his first being seen there was radiological evidence of union of both fractures, although complete consolidation of the original fibular fracture had not yet taken place (Fig. 4). Clinically there was some residual bone thickening of the lower tibia which increased the girth of the leg at this point by a quarter of an inch. The fibular thickening had disappeared. Joint movements were unrestricted and the patient had resumed full normal activities. He was playing football and cycling but had not yet tried long distance running. It was notable that his height had increased in the year by about three inches.

Radiographs of the rest of the skeleton showed no abnormality of ossification of the epiphyses. Control radiographs of the hand showed no porosis. Blood examination was normal.

DISCUSSION

Fatigue fractures of the lower tibia and of the lower fibula follow a well defined pattern and this case is no exception. According to Burrows (1948) the young runner's fracture in the lower fibula is found two inches or more from the tip of the lateral malleolus and in the middle-aged woman the fracture is through mainly cancellous bone about an inch lower down. Similarly in the lower tibia, where only eight fatigue fractures have been published, the elderly or middle-aged person sustains the fracture through the expanded lower end of the bone about two inches above the medial malleolus (Singer and Maudsley 1954) whereas when the fracture has occurred in young men it has been higher up the shaft (Blumenfeld 1943, Krause and Thompson 1943). The fractures in my case follow the now familiar pattern in both the tibia and fibula, being at the higher or young person's level.

There can be little doubt that the tibial lesion was a true fatigue fracture. The radiological appearance conforms to Hartley's (1942) description, with the band of sclerosis across the medullary space penetrated by the thin radiolucent line. Another characteristic of a fatigue fracture, according to Hartley (*loc. cit.*), is that the processes of destruction and repair are going on simultaneously. Here this is well shown by the early subperiosteal calcification on the medial side which proceeded to bone buttressing, and the infraction of the lateral cortex which extended to become a large area of bone absorption before finally uniting (Fig. 1). The diagnosis of the fibular lesion was not so easily made as in the case of the tibia. The first radiographs showed the appearance of a fracture with delayed union, but this could have been a pathological fracture through a chondroma or through an area of fibrous dysplasia. It was not until the fatigue fracture of the tibia on its lateral aspect began to show a similar appearance after five months that the diagnosis of the fibular lesion was established. Previous accounts have not stressed the delay that may occur in the union of these fractures, except in the case reported by Evans (1955) of a fatigue fracture of the ulna which showed established non-union by the time the patient was seen. An onlay tibial graft promoted

rapid union. In the present case bony union of the tibial fracture was achieved after a year and at the end of this period the fibular fracture was not completely consolidated.

In seeking for an explanation of the unusual indolence of the fibular fracture and the progress of absorption on the lateral side of the tibial fracture attention was directed to a possible underlying endocrine fault. A possible clue was the fact that the patient had grown about three inches in the year. It is known that an adolescent in a period of rapid growth may become liable to slipping of the upper femoral epiphysis, and Harris (1950) produced experimental evidence that an excess of growth hormone decreases the shearing strength of the epiphysial plate in rats. Radiographs of the femoral heads in my patient showed no epiphysial coxa vara and films of the rest of the skeleton were normal. Biochemical tests also failed to reveal any evidence of endocrine dysfunction. It is nevertheless possible that because he was in a stage of rapid growth the tibia was unusually prone to stress. Wolfe and Robertson (1945) stated that " rhythmically repeated mechanical stresses at the point of greatest bone bending can produce fractures of individual trabeculae. This reduces the functional capacity of the bone and overloading then results in a fracture." The overloading in this case may well have been the excessive torsional strain imposed upon the fast growing tibia by the application of a below-knee walking plaster which fixed the foot but allowed the knee to rotate. The patient was aware of discomfort whenever he turned round while in this plaster. This was not a complication that could be foreseen but it is worth recording. It is open to question whether such a plaster was good treatment for a painful lower fibula, but there can be little doubt that the protection of a long-leg plaster should always be advised in the young patients with fatigue fractures relatively high in the tibial shaft, at least until partial consolidation or buttressing is advanced. Unprotected activity may transform a fatigue fracture of the tibia into a displaced fracture (Hartley 1942, Roberts and Vogt 1939, Krause and Thompson 1943, Burrows 1956).

SUMMARY

1. A case is described of fatigue fractures occurring in the lowest thirds of the right tibia and fibula simultaneously.
2. The fibular fracture was a runner's fracture.
3. The tibial fracture was ascribed to the application of a below-knee walking plaster to treat the fibular lesion.
4. Both fractures were slow in uniting.
5. The fractures occurred in a rapidly growing youth but no clinical evidence of an endocrine dysfunction was found.

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THE TORN ACETABULAR LABRUM

A Block to Reduction of a Dislocated Hip

IAN PATERSON, FIFE, SCOTLAND

This short paper describes how the complete reduction of a traumatic dislocation of the hip may be prevented by a soft-tissue block. In both cases described, the labrum, detached like a bucket handle, lay in the hollow of the acetabulum and defied all attempts to obtain a full replacement.

Case 1—An agricultural worker, a man of thirty-eight, fell under a tractor, which ran over the inner side of his right thigh causing a backward dislocation of the head of the femur. Radiographs showed what appeared to be a simple posterior dislocation of the hip with a tiny linear fracture of the postero-superior bony rim of the acetabulum (Fig. 1). Reduction was attempted by a closed manipulation. Clinically the head of the femur appeared to go back into the acetabulum, but a radiograph showed that the reduction was not complete (Fig. 2). It will be seen from the radiograph that the head is low in the acetabulum, there is a wide gap between the upper surface of the head and the lower surface of the acetabulum, and Shenton's line is broken.

It was considered that there was some soft-tissue obstruction preventing complete reduction and so, forty-eight hours after the accident, the hip was opened through a posterior incision. Lying across the floor of the acetabulum, blocking reduction, was the detached cotyloid ligament—the fibrocartilaginous rim of the acetabulum. It was firmly attached at both ends and lay tightly across the articular surface (Fig. 3). It had to be pulled out forcibly by a hook. It was excised and the femoral head could then be reduced completely. The rent in the capsule and a tear of the short lateral rotator muscles, made by the original dislocation, were repaired and the hip was immobilised. The post-operative radiograph showed normal relationship of head and acetabulum (Fig. 4).

Case 2—A similar case had been seen three years before. A man of twenty-one, who fell from his fast-moving motor cycle, suffered concussion and was unconscious for a time, so that it was not until two weeks later when he was up and about that he complained of pain in his hip. A radiograph showed a subluxated hip, a wide gap between the femur and the acetabulum, and a small bony loose body within the joint (Fig. 5). At the time of the accident this hip may have been dislocated and the fibrocartilaginous rim of the acetabulum torn off and with it a tiny fragment of bone. Spontaneous reduction would have trapped the loose fragment within the joint. This hip also was explored through a posterior incision. After the head of the femur had been dislocated it was seen that the whole of the postero-superior fibrocartilaginous rim of the acetabulum, with an attached fragment of bone, was lying deep in the acetabulum. The detached part of the rim was excised, the hip reduced, the capsule repaired, and the patient immobilised in a plaster spica for six weeks. Weight bearing was allowed after two months. The man has been back at full work for two and a half years and has no disability. Recent radiographic examination showed a normal hip joint (Fig. 6).

DISCUSSION

Posterior dislocation of the hip is most commonly caused by a force acting along the line of the femur when it is flexed and adducted. In this position the head of the femur is forced out on to the dorsum of the ilium, rupturing the capsule of the hip. If the femur is less flexed and less adducted a fracture of the rim of the acetabulum is more likely to occur. The size of the fractured fragment increases with a lessening of flexion until in the extreme

FIG. 1

FIG. 2

Case 1. Figure 1—Initial radiograph. Figure 2—After closed manipulation. Reduction is incomplete.

FIG. 3

FIG. 4

Case 1. Figure 3—Prepared specimen to show how the detached labrum lay across the acetabulum. Figure 4—Radiograph after excision of the labrum.

position of full extension and abduction of the femur a central dislocation of the hip occurs. It is believed that the fibrocartilaginous rim may be split from the acetabulum by the femoral head dislocating backwards, much in the same way as the labrum of the shoulder joint may

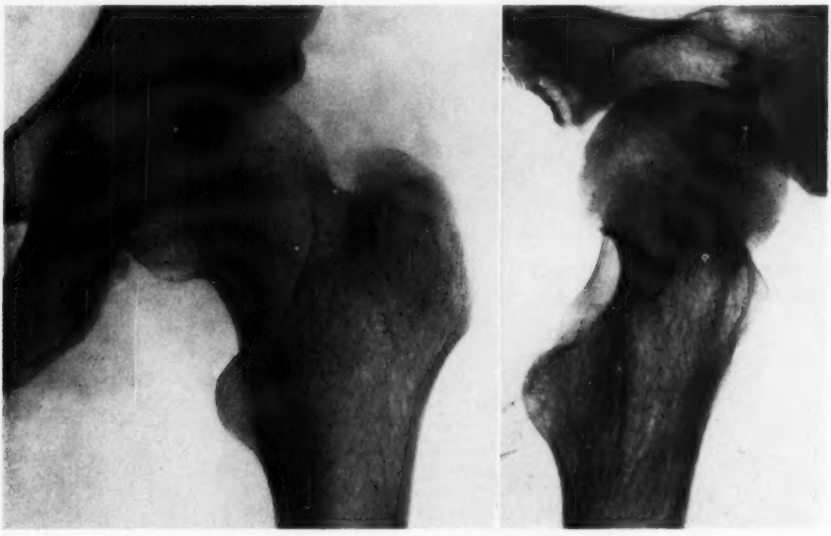

FIG. 5
Case 2—Subluxation of hip with bony fragment between the joint surfaces.

FIG. 6
Case 2—Two years after excision of fragment.

be torn from the glenoid in the Bankart lesion. If the dislocating force persists the femoral head rides over the loosened acetabular rim on to the dorsum ilii, tearing or stretching the capsule which is attached beyond. When the head is reduced the loose fibrocartilaginous

fragment is pushed in front of it, into the acetabulum, and lies, like a bucket handle tear of a cartilage in the knee, blocking full reduction. Once in this position it is locked by the femoral head and will not go back into place spontaneously. In Case 2 the leg had borne weight, the displacement was not noted for fourteen days, and at operation the fragments could not be withdrawn from the hip until the fractured hip had been redislocated; in Case 1, although operation was only forty-eight hours after the accident, the fibrocartilaginous rim had to be pulled forcibly out of the acetabulum.

It is clear that the diagnosis cannot be made clinically. At the time of the initial reduction the femoral head appears to slip truly into the acetabulum and the reduction appears stable and spontaneous redislocation does not occur. Even at open operation redislocation of the head was not accomplished without some force.

Diagnosis is radiological, and a block to reduction can be recognised only by radiographic demonstration that the head of the femur is not fully reduced in the acetabulum. The head lies abnormally low and laterally in the acetabulum. The gap between the bones is greater than that on the other side. The line of the head does not conform to the line of the cup of the acetabulum and there is a break in Shenton's line. That a detachment of the fibrocartilaginous rim exists may be suspected from a radiograph such as that shown in Figure 1, in which there is a linear marginal fracture of the acetabulum. When bony fragments of the acetabular rim are detached and can be seen lying within the joint the diagnosis can be made with more ease and certainty (Fig. 5). When the bony fragments are small and difficult to see (Fig. 2) the diagnosis may be missed. If this mistake is to be avoided it is suggested that good quality antero-posterior and lateral radiographs must be taken immediately after the reduction of any dislocated hip, especially if a plaster spica is to be applied for subsequent immobilisation.

SUMMARY

Complete reduction of a dislocated hip may be blocked by a partial separation of the acetabular rim. The diagnosis is radiological and is easily missed. Treatment is by open operation and resection of the partly detached fibrocartilaginous rim.

I wish to express my grateful thanks to Professor Bryan McFarland for his helpful suggestions and stimulating interest in this paper.

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FRACTURE-DISLOCATION OF HIP WITH DISPLACEMENT OF BONE FRAGMENT INTO ACETABULUM DURING CLOSED REDUCTION

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Fracture-dislocations of the hip complicated by displacement of a fragment of bone into the acetabulum at the time of manipulative reduction are uncommon. Armstrong (1948) made no mention of such a case in forty-three examples of hip dislocation associated with fracture of the acetabular rim, nor did Thompson and Epstein (1951) in their large series of dislocations and fracture-dislocations of the hip. Urist (1948), however, in a series of twenty-seven fracture-dislocations of the hip described three examples and gave details of the treatment afforded. A further case is reported here in which an important variation in treatment was used and is recommended.

FIG. 1

Initial radiograph showing posterior dislocation of the hip. The detached fragment of acetabular rim can be seen behind and below the femoral head.

A man aged twenty sustained a posterior dislocation of the right hip with fracture of the posterior rim of the acetabulum (Fig. 1). Manipulative reduction was attempted about five hours after the injury by the method recommended by Watson-Jones (1955). Radiological examination after what appeared to be a successful closed reduction showed a large fragment of bone lying between the head of the femur and the acetabulum (Fig. 2). At exploration of the hip from behind (Kocher 1907, Gibson 1950) it was possible to remove the fragment of bone from the acetabulum, together with a large piece of infolded posterior capsule, without redislocating the hip. This was accomplished merely by pulling upon the leg and so increasing the space between the femoral head and the acetabulum. Figure 3 shows the hip after removal of the bone fragment. The difference in the depth of the joint space in Figures 2 and 3 is very obvious.

It is important to stress that the posterior approach to the hip joint is the exposure of choice in such cases because it inflicts no further injury on the structures close to the joint.

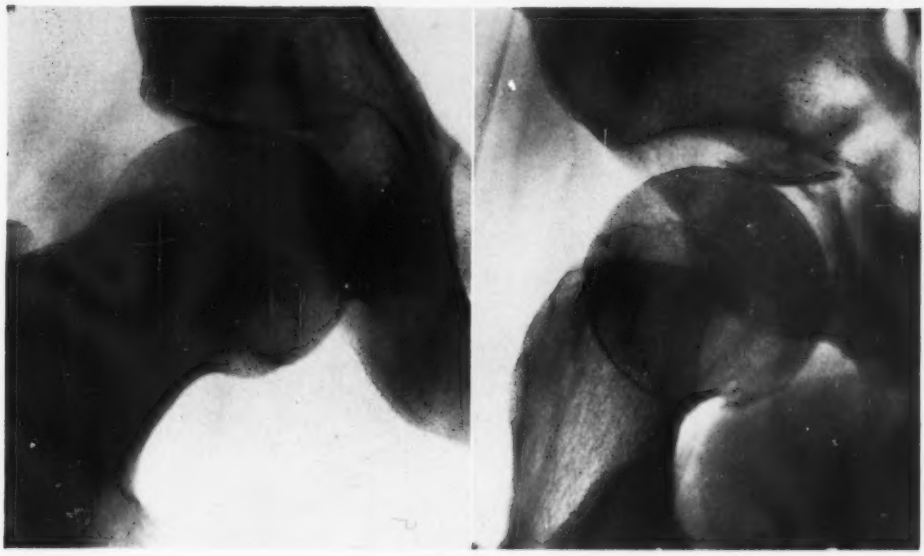

FIG. 2

Radiographs showing the fragment of acetabular rim displaced into the hip joint. The widening of the joint space is noticeable especially when compared with Figure 3.

FIG. 3

FIG. 4

Figure 3—Radiograph after removal of bone fragment. Figure 4—Radiograph six months after injury. Some heterotopic new bone is present at the back. Movements are full.

Thus in this case no other structure was divided than skin, subcutaneous tissue and gluteal aponeurosis. The deeper and damaged lateral rotators and capsule needed only to be retracted to give adequate exposure. The pyriformis muscle was found ruptured. Urist (*loc. cit.*) removed similar fragments of bone by an anterior approach in his three cases. In the case illustrated in his article, which closely resembles this one, he referred specifically to incising intact anterior capsule for this purpose. The femoral head subsequently underwent avascular necrosis.

Figure 5 is a photograph of the fragment removed. Acetabular labrum [cotyloid ligament, glenoid labrum] is shown above, articular cartilage in the centre and fractured bone surface below.

FIG. 5

Photograph of the fragment of bone removed. Acetabular labrum is shown above, articular cartilage in the centre and fractured bone surface below. The fragment measured four and a half centimetres in length.

The patient was treated by rest in bed with light skin traction for six weeks. He was then allowed to walk with crutches but without bearing weight on the affected limb for a further six weeks, when full weight bearing was resumed.

Figure 4 is a radiograph of the hip joint between six and seven months after the injury. Although this shows some new bone behind the joint there was no restriction of movement and the patient was at full work as a garage mechanic. He was not complaining of any symptoms. Re-examination six months later showed no deterioration.

SUMMARY

A case of posterior fracture-dislocation of the hip complicated by displacement of a segment of the acetabular rim into the joint at the time of closed reduction is reported.

In treatment, it is stressed that the posterior approach to the hip should be used to minimise further damage to the soft tissues about the joint.

I am indebted to Mr C. O. Dyson of the Pathological Department of the Royal Devon and Exeter Hospital for Figure 5.

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FAMILIAL OSTEODYSTROPHY OF THE SKULL AND FACE

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For many years intermittent attention has been paid to the aptly named phenomenon of leontiasis ossea. Numerous conditions affecting the appearance of the face have been included but the application of a reasonable definition, such as appears in Dorland's Medical Dictionary, makes a considerable proportion of cases unworthy of the designation. Dorland declares the condition to be a bilateral and symmetrical change in the bones of the face and cranium leading to a lion-like facial expression.

Considering only the contracted group of conditions which have been more accurately named I could find no familial incidence recorded. This prompts me to report briefly the findings in three British Columbian children of one family which has been studied and investigated.

These three children, all girls, were first seen in 1953, aged eight, six and two years. The older children were the more affected and a baby brother one year old appeared normal.

FIG. 1

The eldest child. Note the mild facial deformity. The prominences lateral to the nose are bony hard.

Each girl exhibited the broad face with prominent cheek bones which gives the condition its name and it was for this reason that the parents took them to the family doctor. Clinically there was only mild deformity, difficult to demonstrate photographically (Fig. 1). The prominences lateral to the nose were, however, bony hard. Figure 2 reproduces original lateral views of one child's skull. The film on the left resulted when ordinary technique was used, while on the right the same skull is seen using between two and three times the penetration usually required for a normal adult skull. Figure 3 presents recent more revealing views of the same skull. Thickening of the facial bones, as well as of the entire bony plate of the skull and failure of development of sinuses, can be seen. Examination of the actual radiographs

exhibited more effectively an increase in the size of the maxillae and malar bones, with great deposition of bone in the paranasal regions. The normal osseous structure was replaced by bone having a more or less homogeneous appearance which might be described as

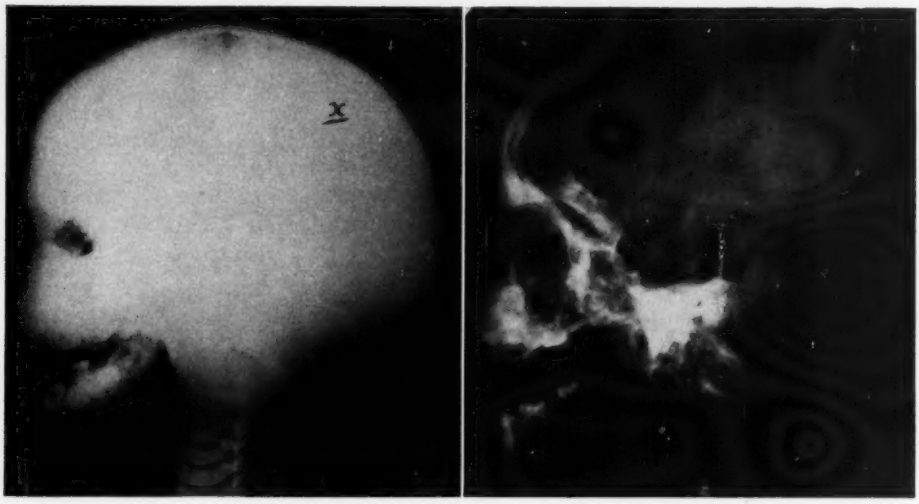

FIG. 2

Initial lateral radiographs. The film on the left was taken using ordinary technique. Between two and three times the penetration usual for a normal adult skull was required for the radiograph on the right.

FIG. 3

Thickening of the facial bones and of the entire bony plate of the skull, with failure of development of the frontal sinuses.

granular. The mandible revealed similar structural changes but without any alteration in the size or shape of the bone. The palate bones and nasal septum all revealed changes in the direction of increased density. The skull revealed evidence of thickening of the vault and base,

most marked in the frontal and occipital regions. It was difficult to differentiate diploe from cortex. Considerable thickening of the walls of the orbit and ethmoidal bones was apparent from the postero-anterior radiographs. All three children revealed similar changes although there were varying degrees of involvement of individual regions. The dentition appeared to have developed and erupted normally. The skull of the male child exhibited similar but less advanced change.

A radiological survey of the long bones in each child failed to reveal any generalised osteopetrosis. General physical examination was quite unremarkable and the children were in no way affected mentally. No relative was known to suffer from this condition. Laboratory investigations including blood Wassermann, mineral metabolism and electrolyte studies, phosphatase estimation and complete blood and urine examination were all within normal limits.

A biopsy specimen consisting of the complete thickness of the skull in the parietal region was removed from the eldest child. The cortex was greatly thickened but not unduly hard. Microscopically the picture was of normal bone.

COMMENT

It is difficult to be certain of the diagnosis in these cases. There is no basis for suspecting an infective origin, such as has been attributed to the local sclerosing leontiasis of the facial bones. The single biopsy was not consistent with fibrous dysplasia, but the radiographic appearances were characteristic of one manifestation of this disease in the face and skull. It is unusual for the distribution of such lesions to produce a leonine facies and to warrant the designation leontiasis ossea.

Further examinations will be necessary to follow the progress of this disease, which may be expected to cease at the time of, or before, the normal cessation of skeletal growth.

Acknowledgment is made of the assistance of Dr H. M. Worth of Vancouver. I gained much from his interest and wisdom in interpreting the radiographs.

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DYSTROPHIA MYOTONICA ASSOCIATED WITH FAMILIAL PAGET'S DISEASE (OSTEITIS DEFORMANS) WITH SARCOMATA

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The skull in dystrophia myotonica—In a previous study of dystrophia myotonica Caughey and Brown (1950) suggested that the endocrine lesion was primarily a failure of the androgenic function of the adrenals and the gonads. In the same paper the authors reported the radiographic abnormalities in the skull in some patients with dystrophia myotonica. In subsequent papers Caughey (1952*a* and 1952*b*) reported further cases of dystrophia myotonica with radiological

FIG. 1
Typical example of skull changes in dystrophia myotonica. Thickened calvarium; hyperostosis; very small pituitary fossa; extensive pneumatisation.

changes in the skull, and it was suggested that such changes should come to be accepted as some of the variable features of the disorder. The changes described were a thickened calvarium, a small pituitary fossa, extensive pneumatisation of the air sinuses, and hyperostosis

* In receipt of a grant from the Dunedin Branch of the Crippled Children Society.

interna (Fig. 1). Walton and Warrick (1954) reported the changes found in seventeen cases of dystrophia myotonica and confirmed the presence of a thickened calvarium and the small sella turcica. They could not confirm the presence of hyperostosis interna or of excessive pneumatisation of the air sinuses. Further investigation however has confirmed our previous

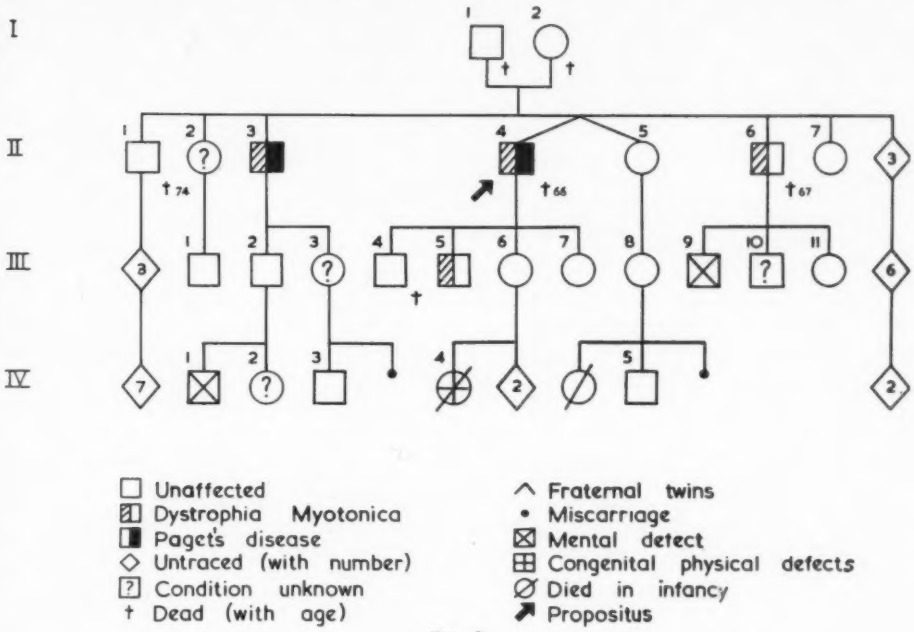

FIG. 2
Family tree.

findings. The incidence of some or all of these skull changes is uncertain, but out of thirty-six cases we have found changes in eighteen. There is no evidence yet reported to suggest that, in dystrophia myotonica, radiological changes occur in other parts of the skeleton.

The skull in Paget's disease—Paget's disease of bone is one of the commonest diseases of bone after the age of thirty years. The lesions have a "spotty" haphazard distribution. In Gutman and Kasabach's (1936) series of 105 cases eighty-two had involvement of the skull (sixty-five with advanced changes and seventeen with early changes).

The usual findings in the skull are early "cotton wool" changes in the frontal and parietal regions, or later a thickened "coarsely moth-eaten" appearance. Osteoporosis circumscripta may occur in association with the "cotton wool" appearance of the calvarium, or it may appear as the only skull change in Paget's disease elsewhere. As the calvarium becomes thickened the distinction between the inner and outer tables and the diplöe is obliterated. The base of the skull tends to sink and platybasia may result.

Familial Paget's disease—Paget (1877), in his original publication, found no evidence of an inherited tendency in the disease; but soon after the original paper it came to be recognised that Paget's disease of bone may occur in families, although uncommonly. Roberts and Cohen (1926) found thirteen instances with an inherited tendency. Since then several authors have referred to the familial incidence of the disease. Hanke (1935) reported a family in which four brothers, their mother and a maternal uncle had the disease. Koller (1946) reviewed the world's literature and found twenty-eight instances of familial Paget's disease of bone.

In a previous publication Caughey (1952*b*) stated that in a patient with skull changes and dystrophia myotonica a differential diagnosis had to be made from Paget's disease and secondary carcinomatosis. Dystrophia myotonica and Paget's disease affecting the skull have in common thickening of the calvarium, but apart from this the diagnosis would be quite apparent to one familiar with the appearance in both disorders.

In view of the feature in common, and the comparative rarity of familial Paget's disease of bone, it is considered worth while to report details of some members of a family which exhibit familial Paget's disease of bone and dystrophia myotonica (Fig. 2).

In this family two members of the second generation have definite dystrophia myotonica and Paget's disease. A third member of the same generation had dystrophia myotonica. In the third generation one member has myotonia with marked psuedohypertrophy, and there is one child who is mentally defective. In the fourth generation there were two children who died at birth, one with gross physical defects, and there is one other child who is mentally defective. Physical and mental defects have previously been shown to occur in families with dystrophia myotonica (Caughey and Barclay 1954). So far as could be ascertained there was no case of consanguineous marriage in the family. The family has been investigated as fully as possible and details of our findings are apparent from the accompanying family tree (Fig. 2).

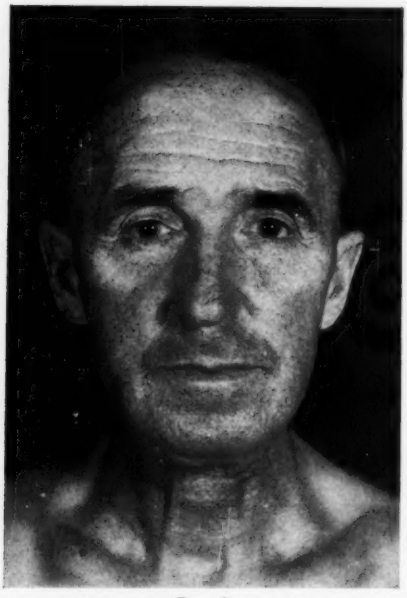

FIG. 3
Case 1—Wasting of temporal and anterior cervical muscles. Frontal baldness.

CASE REPORTS

Case 1—Man aged sixty-six (II,4 in Fig. 2). In 1951 he fell and fractured his right femur at the site of a lesion of Paget's disease. He made an uneventful recovery. Three years later he was readmitted to hospital and stated that three weeks previously he had developed pains in the mid-thoracic region of the spine radiating round the abdomen at the level of the umbilicus. These pains persisted, and five days before admission he developed numbness of the toes and weakness of both legs. For three weeks he had had difficulty in passing urine.

On later direct questioning he stated that he had begun to go bald when he was seventeen or eighteen, and that he had had difficulty in relaxing his grasp for as long as he could recall. He had noticed that his leg muscles were " stiff," and in cold weather he was inclined to fall. From youth until middle life his limb muscles had been very large, although he realised he was not abnormally strong. He had never complained of weakness apart from the disability occasioned by the " stiff " muscles. There had been no impairment of his sex function and his vision had deteriorated very little.

Examination—He was a well developed man, partly bald (Fig. 3). He had bilateral cataract. The temporal muscles were wasted. He had mechanical myotonia of the tongue. The anterior cervical muscles were wasted, and neck flexion was weak; the neck extensors were strong. There was hypertrophy of the biceps group and of the forearm muscles. There was moderate myotonia of the grip on both sides, and mechanical myotonia of the thenar and hypothenar muscles. The power was average, but less than would have been expected with such large muscles.

The abdominal muscles were very weak. He was unable to sit up with arms folded across his chest. There was loss of sweating and loss of appreciation of pain, heat and cold, light touch

and vibration up to a level of the tenth thoracic segment. The upper abdominal reflexes were present; the lower were absent.

In the lower extremities the muscles of the calves and thighs were large. There was mechanical myotonia of the calf muscles. All muscle groups were weak, especially the gastrocnemei muscles. The deep reflexes in the arms were all present, but in the lower extremities all deep reflexes were increased and the plantar responses were extensor. The prostate gland and testes were normal to palpation.

Investigations—Radiography of the lumbar spine and pelvis revealed Paget's disease involving most of the vertebrae and the pelvis. The skull showed thickening of the calvarium, Paget's

FIG. 4

Case 1—Skull showing thickening of the calvarium, Paget's disease of frontal bone with sarcomatous change, and extensive pneumatisation of frontal sinuses.

disease of the frontal bones with sarcomatous changes, and extensive pneumatisation of the frontal sinuses (Fig. 4). There had been some enlargement and compression of the lumbar and thoracic vertebrae, causing some encroachment upon the neural canal. This was most marked in the upper lumbar region. The left clavicle and both femora had manifest evidence of Paget's disease. The serum alkaline phosphatase was 68 units.

Operation—Two days after admission his legs became progressively weaker and the sensory impairment more complete. In view of the clinical findings and the radiological changes myelography was considered unnecessary, and Mr R. G. Robinson carried out a laminectomy at the level of T.8–11. When the upper two laminae were removed there was found a large extradural mass arising from the laminae and enveloping the dura. This was most marked

on the left side and the pedicles and body were involved. It seemed apparent that there was sarcomatous change at the site of the Paget's lesion.

Progress—After operation the muscle power slowly returned, but he became incontinent of urine and an indwelling catheter became necessary. He continued to make good progress with his walking, but two months after the operation he slipped and fell in hospital and fractured his right femur. Radiography revealed a pathological fracture at the site of a Paget's lesion. The leg was splinted with traction, but in the course of the next two months his general condition deteriorated. He developed three large soft swellings over the vertex. He died in April 1955.

Necropsy—The forearm and calf muscles were very well developed. The skull was thickened, soft and brittle. Three separate expanding lesions were observed in the vault, varying from

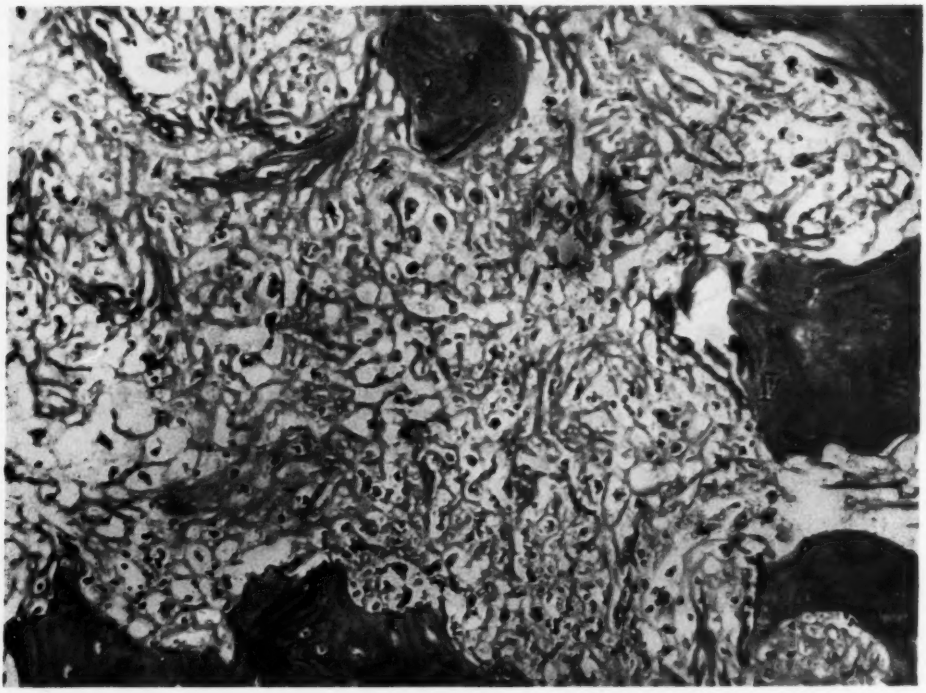

FIG. 5

Case 1—Skull showing Paget's disease with sarcomatous changes. (×120.)

four to eight centimetres in diameter. Histological examination revealed in all sections the irregular thick trabeculae of Paget's disease. In the neoplastic areas the marrow spaces were filled with solid sheets of spindle-shaped and round cells characteristic of an osteosarcoma. There was some formation of tumour bone; and osteosarcomatous deposits were seen in the dura in relation to the skull lesions (Fig. 5).

Muscular system: The sternomastoid muscles showed marked atrophy, and the gastrocnemei, quadriceps and vertebral muscles showed severe changes. The fibres varied considerably in size and were separated by broad strands of collagen. Degenerative change was seen in the fibre cytoplasm, with loss of striation, vacuolation and uneven staining reaction. Islands of adipose tissue were seen in many sections (Fig. 6). The gastrocnemei showed marked fibrous replacement in some of the sections. A few atrophied fibres only remained

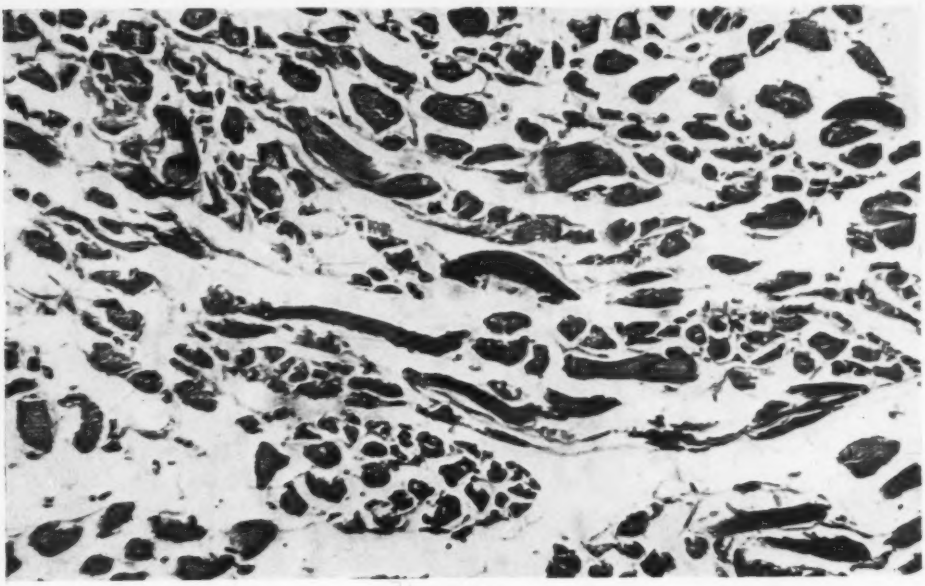

FIG. 6

Case 1—Section of right sternomastoid muscle. Marked variation in fibre size, atrophy and replacement by adipose tissue.

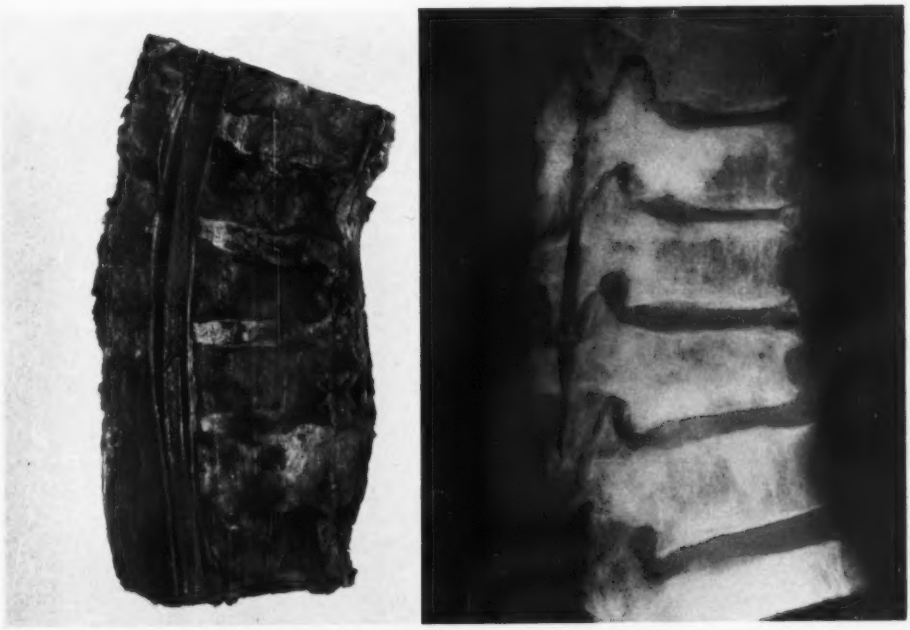

FIG. 7

Case 1—Sagittal section and radiograph through lumbar vertebrae with Paget's disease and osteosarcoma with encroachment on the spinal canal.

and these were separated by dense collagen. The quadriceps muscles showed negligible scarring and there was great variation in the fibre size. The arm flexors showed variation in fibre size with varying degrees of sarcoplasmic degeneration. A striking appearance was the presence of a number of fibres which were represented by a peripheral zone of homogeneous cytoplasm, the centre of the fibre being empty.

Skeletal system: The vertebral column was removed, deep frozen, and sectioned sagittally through the spinal canal. The lower thoracic and upper lumbar vertebrae were irregularly expanded and there was infiltration of the vertebral muscles by tumour. The cut surfaces of the vertebrae were pale and mottled, and of soft texture. The neoplastic process had invaded and encroached upon the spinal canal with compression of the cord in the lumbar region (Fig. 7). The inner two-thirds of the left clavicle were diffusely expanded, measuring four centimetres in diameter. The right femur was expanded, and the cortex irregularly destroyed with infiltration of the muscles by tumour; there was extensive neoplastic change at the site of a healed fracture near the middle of the shaft.

Histologically in all the bones described the features of Paget's disease could be recognised. Thick irregular bony trabeculae showing the characteristic, haphazard mosaic pattern, were prominent. The marrow spaces were filled by neoplastic spindle cells and round cells with occasional tumour giant cells. Tumour bone was also prominent in some of the sections. Similar sarcomatous deposits were seen in the vertebrae and thigh muscles.

The testes were of normal size, and histological sections revealed a diffuse fine scarring, although seminiferous tubules showed only minor atrophy.

Case 2—Man aged sixty-seven years (II, 3 in Fig. 2). In 1951 when getting off a tram he was struck by a car and dislocated his right hip. He was admitted to hospital, where the dislocation was reduced. While in hospital he complained of pain in the left hip, and radiographs revealed Paget's disease of the left femur with associated osteoarthritis. The lumbar vertebrae and pelvis were also affected with Paget's disease. Radiographs of the skull showed a normal pituitary fossa and normal pneumatisation of the sinuses. There was, however, generalised thickening of the calvarium. No definite evidence of Paget's disease was seen in the skull.

When interviewed in 1955 during the investigation of the family, he stated that he had noted difficulty in relaxing his grasp for as long as he could remember. He noticed some difficulty getting up from a chair on account of " stiffness," and when playing bowls he sometimes had difficulty in relaxing his grasp of the wood.

On examination he had frontal baldness and marked leucoderma of the face and limbs. There were bilateral lenticular opacities with cuneiform clefts and streaks; there were also numerous grey punctate opacities throughout the anterior lens cortex, and there were a few in the posterior cortex. No angioid streaks were seen in the retina. There was mechanical myotonia of the tongue and of the small muscles of the hands in the thenar and hypothenar eminences. There was voluntary myotonia on gripping which disappeared after repetitive grasping. The facial muscles were normal. There was weakness of the neck flexors and of the abdominal muscles. He had difficulty in sitting up from the lying position. There was little wasting of the forearms. The deep reflexes were all present. There was no obvious gonadal atrophy.

Case 3—Man aged thirty-five years (III, 5 in Fig. 2). This patient was interviewed during the investigation of the family. At the age of nine years he noticed difficulty with " stiff " muscles and once when starting to run in a race he fell because of tightening of his leg muscles. He had noticed difficulty relaxing his grasp all his life, but this had caused little inconvenience. He was aware that this myotonia was relieved after taking alcohol. He began to go bald at twenty. As a younger man he did a great deal of wrestling. He always had large muscles but, although fairly strong, was aware that his strength was not in proportion to the size of his muscles.

On examination he had frontal baldness and was very muscular. The lenses were normal

to direct examination. No slit-lamp examination was made. There was mechanical myotonia of the tongue and of the thenar and hypothenar eminences. He had well marked myotonia of the grip, which passed off after gripping three times. There was some hypertrophy of the masseter muscles but no facial weakness. The neck flexors and extensors were strong. The biceps muscles and the forearm muscles showed marked hypertrophy. The power was moderately good and equal, but not in keeping with the size of the muscles. There was hypertrophy of the thighs and calf muscles, and mechanical myotonia of the calf muscles. The power was not commensurate with the muscle size. All deep reflexes were present and equal. The gonads were normal to palpation, and radiographs of the skull and pelvis were normal.

DISCUSSION

It is necessary first to attempt to establish the diagnosis of the disorders affecting this family. The development of Paget's disease of bone in two brothers could be coincidental, but we take it to be an example of familial Paget's disease.

The nature of the muscular dystrophy too, is open to discussion. The patient in Case 1 had myotonia and hypertrophy for many years and at the age of sixty-six made no actual complaint of muscle weakness. On examination he had obvious weakness of the neck flexors and the abdominal muscles. The marked histological changes in the sternomastoid muscles and in the gastrocnemei muscles strongly support the diagnosis of dystrophia myotonica. This was further supported by the presence of cataracts. In Case 2 myotonia had been apparent for years, but no obvious hypertrophy. There were well marked myotonia, weakness of neck flexors and abdominal muscles and bilateral lenticular opacities, which is very comparable with Case 1. Although no muscle biopsy has been obtained to support the diagnosis, it is felt that there is adequate evidence to support the diagnosis of dystrophia myotonica of very slow development. In Case 3 the clinical picture at thirty-five was that of myotonia congenita (Thomsen's disease) but the natural history of this familial disorder, as seen in this patient's father and uncle, suggests that other dystrophic features will develop later in life. The diagnosis will be discussed in greater detail elsewhere, but it is our opinion that this family has dystrophia myotonica.

The signs and symptoms of dystrophia myotonica are usually obvious, and seldom could there be any confusion in diagnosis from Paget's disease. The occurrence of familial Paget's disease in a family with dystrophia myotonica does, however, raise some points of interest on account of the radiological changes in the skull in both disorders.

The level of serum alkaline phosphatase, as in other conditions in which bone matrix is being laid down in excess, is high in Paget's disease—in fact, higher than in any other condition. In Case 1 it was 68 units. In dystrophia myotonica, on the other hand, Caughey and Brown (1950) found no change in the alkaline phosphatase in five fully developed cases. In one other case two estimations were 17–22 (King Armstrong units). Thus it seems that the level of serum alkaline phosphatase may be a useful biochemical aid in the differential diagnosis.

In Table I the radiological changes in the skull in both disorders have been tabulated. It will be noticed that the ages differ, but that general thickening of the calvarium may be common to both. On occasions this may be the only abnormal radiographic feature (as in our Case 2) and we are unable to state in this case whether it was due to Paget's disease or to dystrophia myotonica. However, it is most unusual that the diagnosis cannot be made with confidence on account of other signs and symptoms of either disorder.

The sarcomatous changes—Finally, there are some points of interest in the bony lesions. A relationship between Paget's disease and the development of osteosarcoma was noticed by Paget himself (1877). Frequent reports of such an association have appeared since. Willis (1953) estimated that osteosarcomata may be expected to occur in 5–10 per cent of cases of Paget's disease. Assessment is difficult because of the large number of symptomless cases of

Paget's disease that are not diagnosed. Willis (1953) considered that most patients over sixty years of age with osteosarcoma have Paget's disease. Coley and Sharp (1931) found Paget's disease in only 28 per cent of seventy-two cases of osteosarcoma occurring in patients over the age of fifty. Moore (1944) found Paget's disease in 25 per cent of a similar group. Knaggs (1925), Speiser (1928) and Sear (1936) considered the relationship to have been exaggerated. From a review of the literature Summey and Pressly (1946) confirmed the general opinion that Paget's disease is a presarcomatous condition. They found a reported incidence of sarcoma varying from 2–14 per cent of cases of Paget's disease. The observations of Jaffe (1933) were similar, and Bird (1927) found seven cases in sixty-four patients with Paget's disease.

It has been observed that only those bones showing the changes in Paget's disease develop osteosarcoma. This was pointed out by Coley and Sharp (1931) and by Albertini (1928). Jaffe (1933) considered that the great proliferative capacity of the tissue in the marrow spaces in the disease is the basis of tumour formation. Albertini (1928) described a pre-invasive

TABLE I

RADIOGRAPHIC CHANGES IN THE SKULL IN DYSTROPHIA MYOTONICA AND IN PAGET'S DISEASE

	Dystrophia myotonica	Paget's disease
	Age—30–50 years	Age—50–70 years
Thickness of calvarium	Increased—moderately—usually begins in the frontal region	Increased—grossly—variable—often greatest in the frontal region—usually diffuse but may be localised
Shape of vault	Retained unchanged	Changed
Skull tables	Easily identified	Outer table affected
Hyperostosis interna	Common (frontal and/or parietal)	Nil
Pituitary fossa	Normal to very small (occasional ossification of diaphragma sellae)	Normal unless partly effaced by involvement of the skull base
Pneumatisation of sinuses	Usually extensive with large frontals—and back to posterior clinoid processes	Usually normal
Lower jaw	May be prognathic	Normal unless involved with Paget's disease
Osteosarcomatous change	Not reported	Relatively common
Skull base	Not involved	Involved in late stages—platybasia

neoplastic change in the marrow tissues which he believed to be intermediate in nature between Paget's disease and sarcoma. We observed concurrence of undisturbed Paget's disease architecture with definite osteosarcoma in the same sections in some of our material.

The stimulus to neoplastic change has been discussed by Summey and Pressly (1946). Injury to bone has been incriminated by some, but this relationship is not well substantiated. It is unusual for sarcoma to develop at the site of a pathological fracture complicating Paget's disease. Summey and Pressly (1946) referred to a paper by Stöhr (1929) who reported twelve cases, none of which led to sarcoma. However, occasional cases of sarcoma at the site of fracture have been recorded, and it seems that fracture does not increase the likelihood of malignant change, nor does it preclude it.

The occurrence of multiple growths arising simultaneously in many bones affected by Paget's disease has often been reported. The simultaneous appearance of the lesions only in bones showing osteitis deformans, and the absence of lesions in the lungs and other sites, seem to preclude the possibility that these multiple tumours might be metastatic deposits

(Coley and Sharp 1931, Davie and Cooke 1937). The evidence in our case is strongly in favour of the view that the lesions are multiple primary tumours. Sarcomatous change occured in a vertebral column lesion. We can find no record of such a change.

SUMMARY

1. A report is given of a family suffering from dystrophia myotonica and familial Paget's disease of bone.

2. Radiological changes in the skull occur in both disorders, which are quite dissimilar. Thickening of the calvarium, however, may be common to both.

3. The serum alkaline phosphatase is high in Paget's disease and normal in dystrophia myotonica.

4. In one patient the Paget's disease was complicated by the development of multiple sarcomata. Sarcomatous involvement of the vertebral column, observed in one of the cases, has not been recorded before.

It is a pleasure to thank physicians and surgeons who have given us access to their cases, and also Dr A. Veale for advice in the genetic aspects of this paper. We are indebted to the members of the Photographic and Artistry Departments of the Otago Medical School for the photographs and the family tree, and to Miss J. Smith for secretarial assistance.

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TREATMENT OF TUBERCULOUS SINUSES AND ABSCESSES OF OSTEOARTICULAR ORIGIN

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The conservative treatment of bone and joint tuberculosis has been the universally accepted method of management until recent years. The older authors repeatedly warned against disturbing these bony lesions. Calot (1923) used to say: " To open an abscess is to open a door through which death almost always enters." According to Dickson (1945) " introducing a drainage tube into a tuberculous abscess makes certain that a draining sinus will form, which will become secondarily infected, which probably will never heal."

Rest, fresh air, good diet and adequate splintage still play an important part in the treatment of skeletal tuberculosis. But alone they are of little avail in the presence of sinuses, and many cases of tuberculous abscesses proceed to sinus formation in spite of conservative treatment combined with repeated aspiration. Formerly such cases presented a baffling problem, and many heroic measures were adopted by enterprising surgeons; these could hardly be considered elective surgery and really amounted to surgery of despair. The advent of streptomycin and other anti-tuberculous drugs has changed the prospect in these patients. With prolonged chemotherapy some sinuses heal spontaneously, but some persist indefinitely.

Brock (1947) used streptomycin in twelve patients with sinuses. Eleven showed improvement and the sinuses healed within twelve to twenty weeks. He found that healing was more rapid when free drainage from the sinus was present, and cases with pent-up collections of caseous matter responded less satisfactorily.

Ahern (1950) published a series of eighteen cases treated by local instillation of streptomycin daily through a catheter, and obtained healing in two to sixteen weeks. The result suggests that treatment by local instillation of streptomycin hastens healing in favourable cases.

Closure of the sinus does not necessarily imply healing of the underlying lesion. Prolonged treatment is still needed; there is inevitable loss of function of the affected joint; and in some patients the treatment fails.

This comparative failure of anti-tuberculous drugs administered either parenterally or locally is probably related to the nature of the local tissue reaction to tuberculous infection. Boyd (1955) stated that a tuberculous obliterative endarteritis followed by periarteritis was a constant feature in tuberculosis of bones and joints. This is very marked in the late stages when the lesion becomes chronic. In many cases the infection leads to the formation of sequestra which are completely avascular, and these sequestra harbour tubercle bacilli. Because of the avascularity of the lesion and the fact that a tuberculous focus is usually isolated by a fibrous wall, drugs administered through the parenteral route cannot reach the centre of the diseased area in therapeutic concentrations (Roaf 1954*a*, 1954*b*). Even if administered locally through a sinus, the drug cannot be uniformly diffused throughout the diseased area. Unless a pathway is opened surgically to allow the drugs to gain access, they can act only indirectly by enhancing host resistance; indeed they may have an undesirable effect by encouraging the emergence of drug-resistant strains of tubercle bacilli.

In making a direct assault on a tuberculous lesion, the surgeon must bear in mind that the devitalised tissues may be unable to deal with secondary infection; and there is always the risk of a general dissemination of the tuberculous infection. The success of anti-tuberculous drug therapy in controlling sinuses and also in the treatment of acute forms of tuberculous lesions, including tuberculous meningitis, raised hopes of success from a direct attack on the tuberculous lesion and focused attention on the lesion underlying the sinus.

Simple incision for tuberculous abscesses and sinuses has not been successful. Bosworth and Wright (1952) found that when the abscess was incised without definitive surgery no wound was healed when the dressings were first removed. The speed of closure was unpredictable. When incision was undertaken without streptomycin two patients out of three died after profuse drainage and cachexia. In patients treated with streptomycin, even when the wound is healed, the permanence of the healing cannot be assured. There is always a risk of reactivation of the primary lesion unless the bony lesion is eradicated. Winterhoff and Weber (1948) stated: " When confronted with a tuberculous abscess or sinus we have not hesitated to make an ample incision, evacuate the necrotic debris and pus and establish free drainage under streptomycin cover. The underlying bone lesion is excised. The wound is packed with gauze, and healed by granulation."

On assessing the results of definitive surgery in twenty-eight cases Smith and I-Sen-yu (1950) concluded that abscesses and sinuses arising from bone and joint lesions healed promptly under the influence of streptomycin provided the primary focus was removed surgically at the same time. Bosworth (1952) maintained that " in thoroughly excised wounds, apart from permanency of closure of sinuses, the skeletal lesion also shows complete healing. No evidence of reactivation either clinically or radiologically was detected during six months to one and a half years of their active life." In a case in which necropsy was performed three years after surgery Deroy and Fisher (1952) found that there was no gross or histological evidence of a tuberculous lesion in the previously involved and treated part.

CLINICAL MATERIAL AND PLAN OF TREATMENT

In the present series definitive surgery under the cover of anti-tuberculous drugs has been performed in forty-four cases of skeletal tuberculosis with abscesses and sinuses during the period 1952–54. Excision of the larger joints and of vertebral lesions has not been included in this review. The site of the lesions is shown in Table I.

TABLE I

SITE OF DISEASE IN FORTY-FOUR PATIENTS WITH SKELETAL TUBERCULOSIS

Site	Number of cases
Metatarsal	10
Cuboid	2
Calcaneum	10
Greater trochanter	6
Pubis	2
Rib	9
Greater tuberosity of humerus	1
Medial condyle of humerus	1
Upper end of ulna	1
Phalanx	1
Lower end of radius	1

In one patient with calcaneal disease both heels were affected; so there were forty-five separate lesions in forty-four patients. Thirty-four patients had sinuses at the time of admission and nine had abscesses without sinuses. In all patients repeated aspiration of the abscess was combined with general and local rest before definitive surgery was performed. The

abscesses seemed likely to rupture spontaneously in spite of aspiration. The duration varied from six months to eight years. No case was discarded from the series on account of age, physical condition, type of lesion or duration of disease.

Treatment always followed a uniform plan. The patient was admitted to hospital three weeks before operation. During this period he was placed on a high calorie diet with adequate amounts of the essential vitamins. This was supplemented by liver extract and iron and other haematinics if there was any evidence of anaemia. The patients were treated with complete rest in bed and the involved area was suitably splinted. The following drugs were given: 1) one gramme of streptomycin daily by parenteral route; 2) 10 to 12 grammes of para-amino-salicylic acid daily by oral route; 3) 200 to 250 milligrams of isonicotinic acid hydrazide daily by oral route. The dose was varied in accordance with the age and weight of the patient.

After this preliminary treatment definitive surgery was undertaken, as follows. Adequate exposure of the involved skeletal structure was gained through the most direct route, preferably

FIG. 1

FIG. 2

Case 12—Tuberculosis of calcaneum and subtalar joint in a girl of nine. Discharging sinus for two and a half years. Figure 1—Before operation. Figure 2—After operation; wound healed.

through the sinus or the abscess. When the sinus was away from the line of incision, the track was thoroughly scraped out. All dead tissues, and especially sequestra, were removed, and diseased structures were ruthlessly excised except the blood vessels, nerves and muscles. Bone was removed fairly widely, the aim being to reach uninvolved areas of the bone beyond the limits of the diseased area. Tuberculous myositis being almost unknown, whenever possible an attempt was made to leave a cavity lined with healthy muscle tissue. The whole surface of the wound was sprayed liberally with dry streptomycin powder. Finally the wound was closed round a soft rubber catheter through which anti-tuberculous drugs were instilled after operation. Primary closure was performed in every case except the first. This was a case of tuberculous disease of the greater trochanter with a large abscess in an old and emaciated woman. Large quantities of pus were aspirated at weekly intervals for two months. Her general condition continued to deteriorate in spite of repeated aspirations and routine conservative care. After definitive surgery the wound was packed with gauze impregnated with

iodoform. The dressings were removed on the third day, when the wound was found fresh and healthy and it healed gradually by granulation.

After operation the affected area was always splinted, usually by plaster-of-Paris. General constitutional treatment and chemotherapy were continued, and each day for three weeks a gramme of dihydro-streptomycin dissolved in two millilitres of normal saline was instilled through the catheter. (The dose was reduced in children.)

RESULTS

When the preliminary plaster was removed three weeks after the operation the wound was found healed by primary intention in every case. In a few cases there was a small collection

FIG. 3

FIG. 4

Case 34—Tuberculosis of first metatarsal in a woman of twenty. Discharging sinus for a year. Figure 3—Before operation. Figure 4—After operation; wound healed.

of serous fluid in the depth of the wound. This could be easily squeezed out through the track left by the catheter. Secondary sinuses that were not included in the operative incision also showed complete healing in most cases. Constitutional treatment and chemotherapy were usually continued for three months. In a few patients secondary sinuses were present at the regional lymph glands. After thorough excisional surgery of the primary focus of infection these healed rapidly without special treatment. When the erythrocyte sedimentation rate was done before and after operation it always returned to normal within four weeks of the operation. Patients who were febrile before operation became afebrile, as a rule, within a week of the operation and the blood condition of the anaemic cases returned quickly to normal. The results in the forty-four patients are summarised in Table II, and illustrative radiographs are shown in Figures 1 to 6.

TABLE II

CLINICAL DETAILS OF FORTY-FOUR PATIENTS WITH SKELETAL TUBERCULOSIS SUBJECTED TO OPERATION ON ACCOUNT OF ABSCESS OR SINUS

Case number	Age	Sex	Site of disease	Duration of disease	Duration of sinus or abscess	Previous treatment	Remarks
1	52	F	Greater trochanter	2 years	Abscess 10 months	Conservative	Cured. No disability
2	25	M	Sixth and seventh ribs	3 years	Sinuses 2 years	Conservative + aspiration	Cured. Full normal activity
3	25	F	Greater trochanter	2 years	Abscess 6 months	Conservative	Cured. No disability
4	27	F	Greater trochanter	8 months	Abscess 4 months	Nil	Cured. No disability
5	22	F	First metatarsal	2 years	Sinuses 10 months	Conservative + incision: chemotherapy	Cured. Use of special shoes
6	18	F	Fifth rib	10 months	Abscess 10 months	Nil	Cured
7	18	F	Fifth metatarsal	1 year	Sinus 6 months	Conservative: chemotherapy	Cured
8	40	F	Fifth metatarsal	4 months	Sinus 3 months	Nil	Cured. Special shoes
9	15	F	Calcaneum	1 year	Sinus 6 months	Homeopathic	Cured. Special shoes
10	3½	M	Phalanges	2 years	Sinuses 1 year	Plaster. Prolonged chemotherapy	Cured
11	19	F	Fifth metatarsal	1 year	Sinus 8 months	Nil	Cured
12	9	F	Calcaneum	3 years	Sinus 2½ years	Conservative + scraping. Chemotherapy	Cured. Special shoes
13	35	F	Pubic symphysis	1 year	Sinus 10 months	Incised by barber	Cured
14	18	M	Greater trochanter	8 months	Abscess 6 months	Aspiration	Cured
15	22	F	Greater trochanter	8 months	Abscess 5 months	Aspiration	Cured
16	19	F	Medial condyle	6 months	Sinus 4 months	Conservative: chemotherapy	Cured
17	12	M	Calcaneum: hip	3 years	Sinus 1½ years	Conservative: prolonged chemotherapy	Cured. Special shoes
18	3	M	Tenth rib	4 months	Sinus 3½ months	Incised	Cured
19	22	F	Cuboid bone	1 year	Sinus 8 months	Incised by barber	Cured
20	25	F	Upper end of humerus	4 months	Abscess 2 months	Nil	Cured
21	26	M	Cuboid bone	1½ years	Sinus 1 year	Operation + chemotherapy	Cured
22	23	F	First metatarsal and first cuneiform	1 year	Sinus 10 months	Nil	Cured. Special shoes
23	6½	F	Fourth metatarsal	2½ years	Sinus 6 months	Conservative: chemotherapy	Cured
24	4	M	Sixth rib	2 years	Sinus 1 year	Conservative	Cured
25	4	M	Calcaneum	1 year	Sinus 6 months	Conservative: chemotherapy	Cured
26	20	F	Calcaneum	1 year	Sinus 10 months	Nil	Cured

TABLE II—*continued*

Case number	Age	Sex	Site of disease	Duration of disease	Duration of sinus or abscess	Previous treatment	Remarks
27	11	F	Sixth rib	7 months	Abscess 6 months	Aspiration. Chemotherapy	Cured
28	6	M	First metatarsal	7 months	Sinus 6 months	Nil	Cured. Special shoes
29	30	F	Symphysis pubis	3 years	Sinus 1 year	Incised. Chemotherapy	Cured
30	45	M	Second metatarsal	1 year	Sinus 10 months	Aspiration	Cured
31	35	M	Sixth rib	1 year	Sinus 7 months	Incised	Cured
32	20	F	First metatarsal	1 year	Sinus 1 year	Nil	Cured. Special shoes
33	8	F	Both calcanea	1 year	Sinus 1 year	Conservative	Cured
34	20	F	First metatarsal	1 year	Sinus 10 months	Operation + chemotherapy	Cured. Special shoes
35	45	M	First rib	1 year	Sinus 10 months	Nil	Cured
36	48	F	Calcaneum: cuboid	1 year	Sinus 10 months	Incised	Cured
37	25	F	Calcaneum	2 years	Sinus 1 year	Conservative	Cured
38	16	F	Olecranon process	3 years	Sinus 2 years	Immobilisation + chemotherapy. Two operations	Cured
39	30	M	Greater trochanter	8 months	Abscess 8 months	Aspiration. Chemotherapy	Cured
40	22	F	Rib	6 months	Abscess 6 months	Aspiration	Cured
41	32	M	Calcaneum	2 years	Sinus 14 months	Conservative	Cured
42	30	M	Eleventh and twelfth ribs	6 months	Abscess 6 months	Conservative	Cured
43	5	F	Calcaneum	1 year	Sinus 8 months	Nil	Cured
44	40	F	Inferior radio-ulnar joint	7 years	Sinus 4 years	Repeated operation. Prolonged chemotherapy	Cured. Wrist band

COMMENT

The results with this form of management have been uniformly successful. The improvement in the patients' general condition after operation has been very striking, especially in cases in which systemic chemotherapy had not been used parenterally for long periods before the operation. The general improvement was not so evident in the patients who had already had specific drug therapy. The local response also has been very satisfactory. Local pain, tenderness and oedema have almost completely disappeared three weeks after operation. In three patients some discharge persisted for a few weeks through the track of the catheter. All these were patients who had had prolonged chemotherapy before operation, and it is possible that the organisms in these cases had become resistant to the drugs. This is one aspect of the risk that attends the indiscriminate use of anti-tuberculous drugs.

In all cases, however, complete healing was achieved by the end of two months, and radiological evidence of healing of the skeletal lesion was seen within three or four months. By that time most patients were able to resume a fairly active life.

It was surprising that none of the patients developed wound infection and all of them healed by primary intention. During the same period a proportion of patients operated

upon at the same hospital for other orthopaedic conditions developed wound infection. In this respect our series differs from other reported series in which the wound has been left open and secondary suture has been performed when healthy granulations appeared. The relative immunity of these wounds from infection from contaminating organisms may be related to local tissue immunity developed as a result of prolonged exposure to infection.

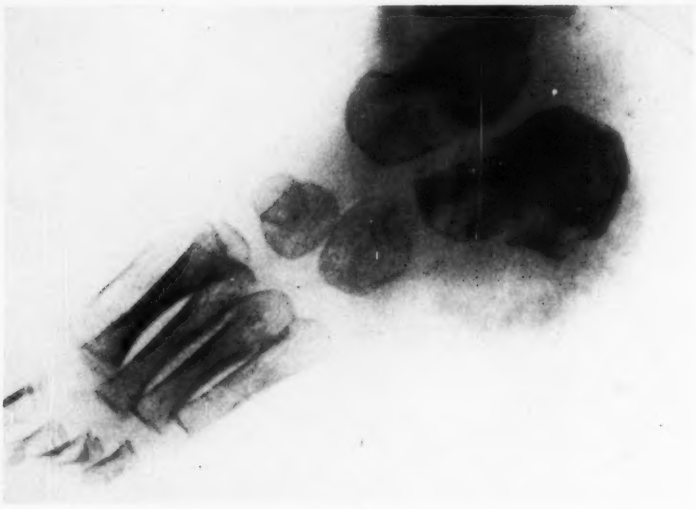

FIG. 5

FIG. 6

Case 25—Tuberculosis of calcaneum in a boy of four. Discharging sinus for six months. Figure 5—Before operation. Figure 6—After operation; wound healed.

The accumulated evidence and the results observed in the present series suggest that the combination of definitive operation with specific drug therapy and general measures is the treatment of choice for tuberculous sinuses arising from bone and joint and in cases complicated by large abscesses. It is clear that surgery is required in such cases when one realises that

multiple sequestra and calcified caseous masses surrounded by thick fibrotic walls were found in many of these cases during operation. We believe that, when the patient has reached this stage, prolongation of conservative treatment only prolongs the suffering of the patient. It seems likely that streptomycin and surgery help each other and ought to be used together if the best results are to be obtained (Roaf 1954*b*). Whereas streptomycin prepares the ground for such surgical procedures, surgery opens the pathway for the antibiotic to have its full effect on the local lesion. In this way surgery performed judiciously may save a limb that would otherwise require amputation. Since the introduction of this method we have not performed a single amputation for tuberculous involvement of a peripheral joint although previously amputations were quite common for late and neglected cases. We agree with Evans (1952) that a time has come when a thorough reassessment of the established methods of treatment of skeletal tuberculosis is called for.

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FORWARD DISLOCATION OF THE ELBOW WITHOUT FRACTURE OF THE OLECRANON

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Watson-Jones (1955) wrote "... in exceptional cases there may even be forward dislocation of both forearm bones without fracture. There is one case in which there can be no doubt about it; the joint was dissected after the limb had been amputated—but that was long ago." This happened in 1860. Forward dislocation of both forearm bones without fracture of the olecranon is in fact extremely rare. The following case is an example of this unusual type of injury.

CASE REPORT

A man aged fifty-seven years was admitted to hospital after having been knocked down by a van and a motor cycle. He had sustained injuries to his left elbow and right leg. On examination the left elbow exhibited a peculiar deformity. The olecranon fossa and the posterior surface of the trochlea were empty and easily palpable. The elbow was held at a right angle with the forearm markedly abducted and supinated. Radiographs of the elbow showed a forward dislocation of both forearm bones, not associated with any fracture (Fig. 1).

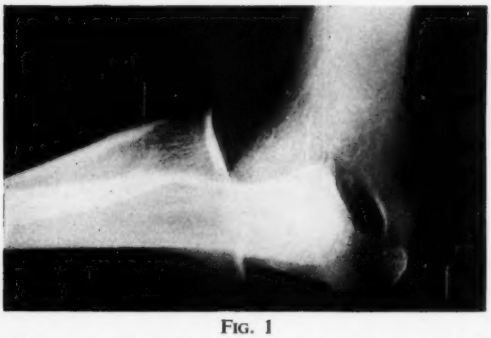

FIG. 1

FIG. 2

Figure 1—Radiograph of the elbow showing forward dislocation of the forearm bones without fracture of the olecranon. Figure 2—Radiograph of the same elbow three months later.

The marked abduction of the forearm made it difficult to obtain a true lateral view of the dislocated elbow. The posterior surface of the olecranon was in contact with the lateral half of the coronoid fossa, the radial fossa and the capitulum.

The dislocation was reduced immediately under a general anaesthetic by gentle traction to the forearm in the position in which it lay, while at the same time the forearm was gradually and slightly adducted and flexed.

Examination after the manipulation revealed no sign of any nerve injury. A collar-and-cuff sling was applied for three and a half weeks. Active movements of the elbow were begun four weeks after reduction. A radiograph showed complete reduction and no sign of any bony injury or abnormality (Fig. 2). Seen eight months later, the patient was free from symptoms; extension of the elbow was to 150 degrees, and flexion, pronation and supination were full.

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DROP-FOOT APPLIANCE WITH CONCEALED SPRING

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The problem of an efficient and inconspicuous drop-foot appliance has taxed the ingenuity of surgical appliance makers for many years. In the Royal National Orthopaedic Hospital's workshops this problem has been studied during the past four years, and various types of apparatus have been constructed.

The apparatus that has now been developed has several particular advantages: 1) the toe-raising device is invisible externally; 2) the power unit—which may be produced in quantity—can be fitted by any appliance maker and is concealed within the heel of the boot or shoe; 3) the special side steels and their spur pieces are easily removed from the spring socket; 4) the side steels are of D-section and relatively thin, but can be heavier if the pressure of a T-strap has to be taken.

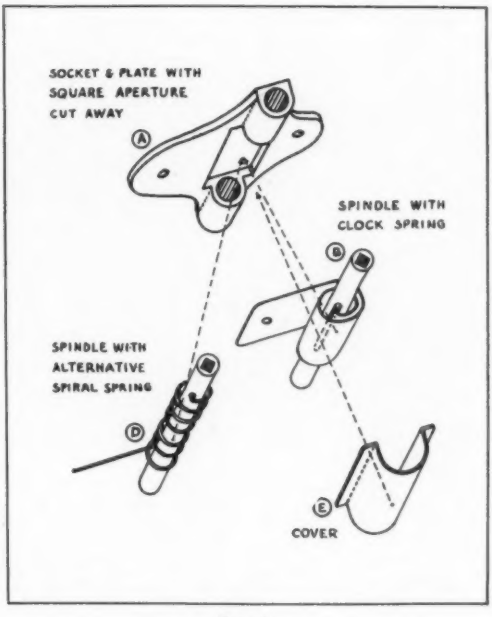

FIG. 1
Constructional details of the power unit.

At present two types of spring are in use—preferably a flat clock spring or alternatively a wire coil spring. The upper ends of the side steels are attached to a calf band and it will be noted that the metal band is in front and the soft part at the back of the leg.

The details of construction (Fig. 1) are as follows. Into an ordinary $\frac{5}{16}$ inch round socket of extruded aluminium is inserted a loosely fitting steel tube of which the internal section is $\frac{3}{16}$ inch square. A central section of 1 inch is cut out of the aluminium socket and this is extended into the plate to a total symmetrical antero-posterior width of $\frac{3}{4}$ inch (A, Fig. 1).

Two $\frac{1}{8}$ inch holes are drilled in the tube for the purpose of lubrication. Before the steel tube is inserted into the extruded aluminium socket a slot is cut in the centre of the steel tube $\frac{13}{16}$ inch long and $\frac{1}{16}$ inch wide directly through the tube, and a $\frac{5}{32}$ inch hole is drilled in the centre of the slot on one side only (B, Fig. 1). A 6-inch length of flat 24 gauge clock spring $\frac{3}{4}$ inch wide is prepared. It is necessary to soften the metal for $\frac{1}{2}$ inch at each end of the spring to allow a $\frac{1}{8}$ inch hole to be punched in the centre of the end of the spring $\frac{3}{16}$ inch from the edge, and to fix a $\frac{1}{8}$ inch iron rivet to the spring, to prevent its pulling through the other slot when the spring is wound. The spring is wound by hand with a crank handle with one end squared to fit into the square socket. When the end of the spring is fixed to the aluminium plate and wound tight the mild steel spring cover is fitted to prevent recoil (E, Fig. 1). Spring tension can be increased by using a wider clock spring, up to a maximum of $1\frac{1}{4}$ inches wide. It will be necessary to increase the cut-out section in the aluminium socket and the slot in the steel tube, according to the width of the spring used. Before the unit is fixed to the shoe it is necessary to remove a small part of the leather seat to receive the under portion of the clock spring.

FIG. 2

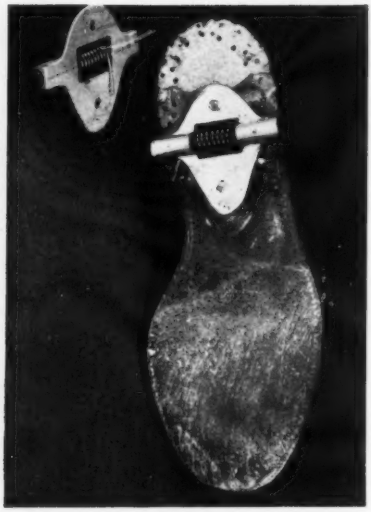

FIG. 3

Figure 2—The clock spring socket without the mild steel cover fitted. Figure 3—The alternative socket with coiled spring.

If a coil spring is used it should be made of 14 gauge first quality spring wire. One end is inserted into a hole drilled in the steel tube, and after seven coils have been wound loosely on this tube the free end is carried forward on to the flat surface of the plate, where a groove has been cut to receive it. It is necessary to wind this spring so that the coils do not bunch together when the tightening action of the toe-raising spring is effected (D, Fig. 1).

The power unit thus constructed is self-contained, and can be fixed in the usual manner of sockets—that is, on the seat and waist of the shoe with two copper rivets (Figs. 2 and 3). The heel is then rebuilt (Fig. 4) but it is important to leave an adequate section in it for the spring to work freely. This cut-out area is lightly packed with Marfak grease before the heel is completed.

The lightest side steels are made of $\frac{7}{32}$ inch D-section steel bar, and the lower ends are turned and made $\frac{3}{16}$ inch square to fit into the heel socket. The upper end is splayed out and a $\frac{5}{32}$ inch hole is drilled $\frac{3}{8}$ inch from the end.

FIG. 4
The clock spring socket built into the heel before the top piece is applied.

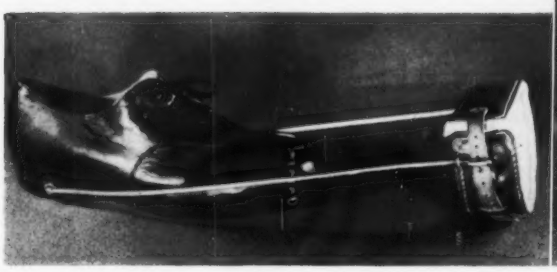

FIG. 5
Figure 5—The position of the instrument and shoe before the tension is applied.

FIG. 6
Figure 6—The position of the instrument in the shoe with the tension applied.

FIG. 7
The spur and socket modified for a full-length appliance. The rounded half of the spur is to sustain weight, and the squared half is to engage in the spring mechanism.

The metal calf band is made of 18 gauge steel 1 inch wide to which are attached the side members by a shoulder rivet on each side. The calf band is thus free to swivel on the side members and so avoid edge pressure on the shin.

It is essential that the metal band should be anterior for the apparatus to work properly. The calf band is then padded and covered in the usual way, and completed by a soft posterior part to which is attached a $\frac{1}{2}$-inch leather strap and buckle.

Method of application—The instrument is applied to the square sockets in the position shown in Figure 5. If the tension is not strong enough the spurs are disengaged from the socket, and the instrument is rotated downwards and the spurs are inserted in the next square position. The instrument is raised to the position shown in Figure 5, and when the instrument is in the position shown in Figure 6 a stronger tension is obtained.

Modifications for a full-length appliance—For a full-length appliance extending to the thigh it is considered that the $\frac{3}{16}$ inch square spur pieces would not be strong enough. This difficulty can be overcome by using the normal $\frac{5}{16}$ inch round spur pieces, leaving half the length of spur nearest to the side piece of the appliance $\frac{5}{16}$ inch round and shaping the other half $\frac{1}{4}$ inch square (Fig. 7). The spring socket is altered by fitting a piece of steel tubing $1\frac{1}{2}$ inches long in the centre of the socket and fixing the spring by the method explained. This will leave at least $\frac{5}{8}$ inch of the socket free at each end to receive the $\frac{5}{16}$ inch spurs, and the centre of the socket will remain the toe-raising unit; each end will take the weight of the appliance in the usual way.

With the full-length appliance the patient may encounter difficulty in getting the foot into the shoe, but that can be overcome by using a long ankle strap which can be slipped lower down the side stems of the appliance until it is directly behind the back of the heel of the shoe; this will keep the shoe at right angles to the appliance, and can be raised to the correct position of the ankle strap when the shoe and instrument are on.

I am indebted to Dr John C. M. Taylor, Ph.D., D.I.C., for the drawings, and to Mr R. J. Whitley, F.R.P.S., for the photographs.

MOVEMENTS OF THE LUMBAR SPINAL COLUMN

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From the University College of East Africa

During the description of new skeletal material in the Department of Anatomy, Makerere College, Uganda, the incidence of certain vertebral exostoses was studied (Allbrook 1955, 1956*a*, 1956*b*). Three well known examples were noted: 1) thoracic laminal spurs (Fig. 1); 2) " beaking " of thoracic spinous processes (Fig. 2); and 3) exostosis formation on the anterior superior border of the vertebral body (Fig. 3).

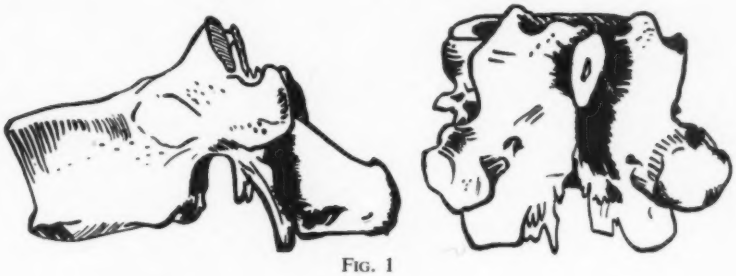

FIG. 1

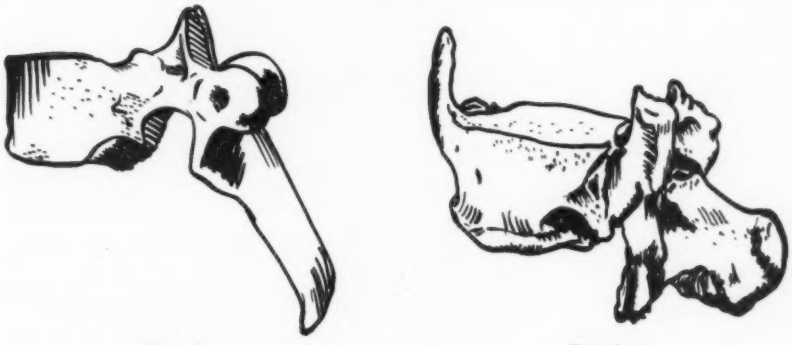

FIG. 2 FIG. 3

Three types of vertebral outgrowths. Figure 1—Thoracic laminal spurs. Figure 2—Beaking of thoracic spinous process. Figure 3—Spur formation on the anterior superior border of a lumbar vertebral body.

In a large number of vertebral columns the distribution of these bony outgrowths relative to the spinal curves suggests that they are produced in response to intermittent postural tension at the point of insertion of ligament into bone. Thus the thoracic laminal spurs occur at the point of insertion of the thoracic ligamenta flava, attaining their greatest incidence at the summit of the thoracic curve; " beaking " of the spinous processes occurs at the point of insertion of the supraspinous ligaments in the same region; and anterior spurring of the body occurs at the point of insertion of the anterior longitudinal ligament, reaching its greatest incidence at the summit of the lumbar lordosis. In Africans this is at the intervertebral disc between L.3 and L.4.

The distribution of these lumbar exostoses suggested the need for a further study of the normal movements of the lumbar spine.

METHODS

Osteological study—During the examination of 206 vertebral columns the incidence of lumbar exostoses was noted in relation to age, sex and tribe. All vertebrae showing an anterior spur on the body more than three millimetres in length were counted.

Morphological study—In a number of spines the anterior longitudinal ligament and intervertebral discs were examined macroscopically and microscopically. Necropsy specimens of the bodies, intervertebral discs and anterior longitudinal ligament in the lumbar region were dissected and fixed in formalin, decalcified in formic acid, sectioned and stained by the Masson-Goldner technique.

Radiological study—Lateral radiographs of the lumbar spine of twenty-five living men and seven living women were taken. Of these subjects, four men and two women were Europeans.

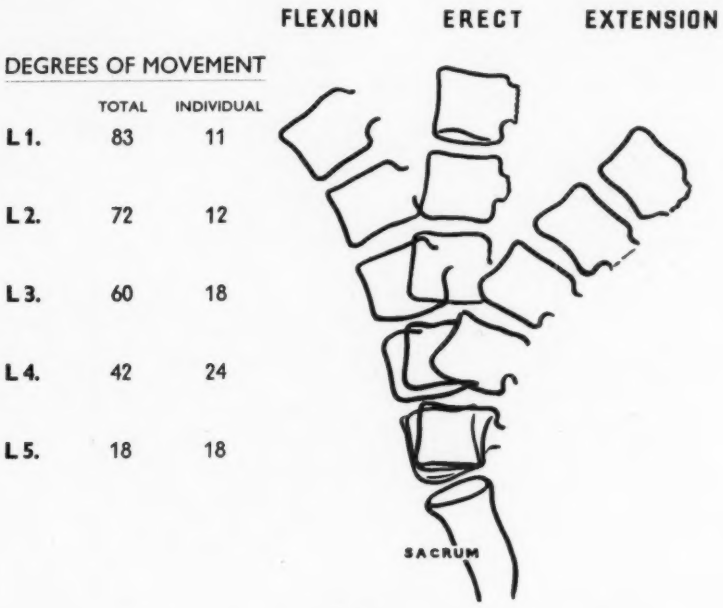

FIG. 4
Tracings from representative radiographs showing the range of movement of the lumbar spinal column.

Radiographs were obtained in full flexion, in the erect position and in full extension. Twenty of the subjects were free from symptoms or signs referable to the back. Eight, in middle age, complained of chronic backache, and radiographs showed typical exostoses on the lumbar vertebrae. Four young people complained of acute backache but showed no bony abnormality. In each case the radiographic shadows of the vertebral bodies and sacrum were traced on transparent paper. The images of the sacrum were superimposed in all three positions of the back, thus giving a fixed point for the measurement of the movement of each lumbar vertebra, between the position of full flexion and full extension. A line was drawn through the mid-point of each vertebral body parallel to its upper and lower surfaces, and projected forwards and backwards. The angle at the point of intersection of the lines in flexion and extension was taken as the total amount of flexion of the column, using the sacrum as a fixed point. From this figure individual vertebral movement was calculated by subtraction (Fig. 4).

RESULTS

Osteological study—Figure 3 shows a typical well formed lumbar vertebral body spur. This lesion is a smooth tongue-like spur of bone arising from the upper midline margin of the vertebral body, which curves upwards and a little forwards as if pressed on by the intervertebral disc lying behind it. Lesions varied from spurs four and a half centimetres long to projections a few millimetres in length. The fourth lumbar was the most commonly and most severely affected (Fig. 5). The upper lumbar region sometimes showed small spurs but they were never well marked.

Sex—Of 180 male skeletons spurring was present in 18·2 per cent. The incidence in twenty-eight female skeletons was 40 per cent.

Age—Adults of all ages were affected, and the distribution curve according to age followed closely that for all the male skeletons in this series. Except in the oldest subjects osteoarthritic lipping was not found in the lumbar zygapophysial facets.

Tribe—No significant tribal variation in frequency was detected.

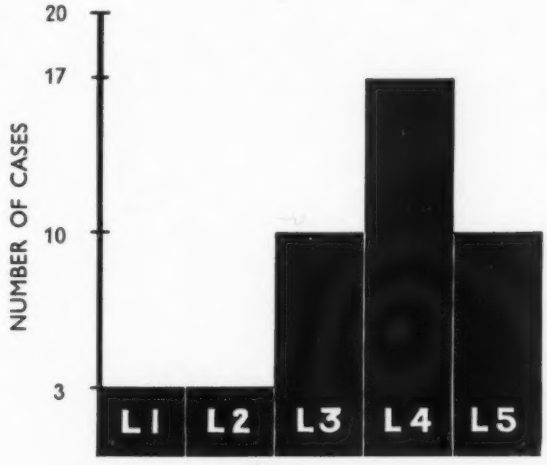

FIG. 5
Distribution of lumbar exostoses (forty-three cases).

Morphological study—Dissection showed that ossification was in the anterior longitudinal ligament, which in the lumbar region is a tough longitudinally lying membrane in contact with the annulus fibrosus of the disc, which blends with the periosteum of the vertebral body (Fig. 6). This was confirmed histologically: the short diagonally placed annular fibres could be seen separated by reticular fibres from the long parallel collagen fibres of the anterior longitudinal ligament. The three groups of annular fibres described by Harris and Macnab (1954) were not seen, but the deep insertion of obliquely placed annular fibres into the cartilage plate was demonstrated. The obliquity of criss-crossing annular fibres was constant for any given region of the vertebral column. Rouvière (1921) noted the same pattern, but different angles were found in the present work. In a number of measurements the annular fibres of the cervical region made an angle of 60 degrees with a sagittal longitudinally placed line; in the lumbar region the angle averaged about 35 degrees. The angle of the annular collagen fibres therefore varies in proportion to the depth of the intervertebral disc.

Radiological study—The thirty-two radiographs were analysed according to race, age and sex, taking as the comparative data 1) the total flexion of the lumbar vertebral column, and 2) the movement of individual vertebrae between flexion and extension.

In a number of films the shadow of the first lumbar vertebra was either partly missing or distorted. For this reason the second lumbar vertebra was taken as the upper end of the lumbar spine for the purpose of calculating the total angle of flexion and extension of the lumbar spine, although all five vertebrae were used when possible.

In healthy, pain-free individuals the greatest movement occurred in the lower lumbar vertebrae. In nine cases the greatest movement occurred at L.4. In six cases the greatest movement was at L.5, and in six there was an equal angle of movement at L.4 and L.5 (Tables I and II).

Although the number of Europeans and of women examined was small, there was no indication in this series that a difference in the flexibility of the lumbar column was associated with race or sex. There was a general decrease in flexibility with increasing age.

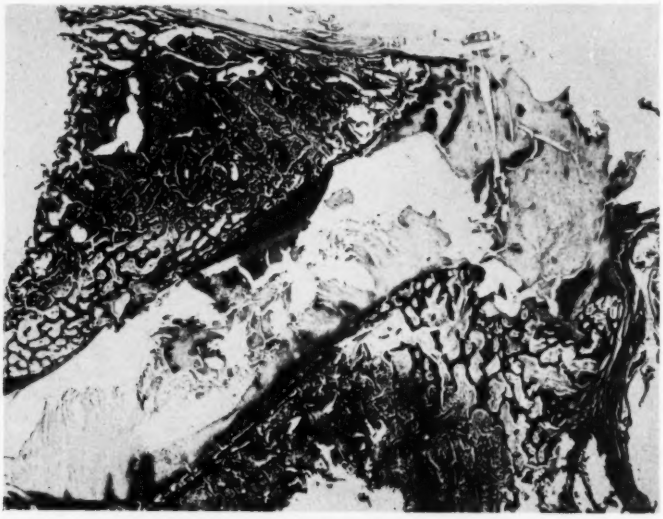

FIG. 6

A well developed anterior exostosis of the fifth lumbar vertebral body. (×2.)

Anterior spur formation in the vertebral bodies was noted only at or after middle age, and it was always associated with limitation of movement of the vertebrae concerned (Table III). In four young patients with acute back pain but without bony abnormality there was a general restriction of movement not confined to one particular vertebra (Table IV).

DISCUSSION

In this series of skeletons the greatest incidence of anterior exostoses was at the fourth lumbar vertebra (Fig. 5). In the radiological study the fourth and the fifth lumbar vertebrae underwent the greatest movement during spinal flexion and extension. These vertebrae are also at the summit of the lumbar lordotic curve, and in East Africans the point of contraflexure is between L.3 and L.4 (Allbrook 1956*b*). The anterior longitudinal ligament at this site is therefore submitted to intermittent strains from the compressed and forward pushing intervertebral disc, both during standing and during spinal flexion and extension.

These observations do not confirm the prevalent view that the total movement of the lumbar spine is small (Charnley 1951, Armstrong 1952). These authors did not produce any evidence from the living subject to support their statements, nor do their published illustrations support or clarify the point. In the investigation of vertebral movement it is essential to

select a satisfactory fixed point from which the angle of movement can be assessed. In the illustrations published by the authors mentioned there is no stated fixed point, although one of the upper lumbar vertebrae was in fact used. This is a convention that masks the true

TABLE I

MALE LUMBAR VERTEBRAL COLUMNS WITH NO BONY CHANGES AND NO SYMPTOMS

Tribe or race	Approximate age	Degrees of movement of lumbar vertebrae					Total movement (*degrees*)	
		L.5	L.4	L.3	L.2	L.1	L.2–5	L.1–5
Ganda	16	11	20	15	11	1	57	58
Ganda	25	16	21	13	10	4	60	64
Hya	20	18	24	16	12	13	70	83
Ganda	21	14	19	10	7	2	50	52
Luo	22	21	18	11	6	—	56	—
Lugbara	26	18	13	23	8	1	62	63
Unknown	*Unknown*	18	21	12	7	—	58	—
Ganda	42	11	27	16	10	8	54	62
Rwanda	50	21	12	12	9	9	54	63
Kikuyu	45	23	16	11	8	7	58	65
Rwanda	35	23	18	9	3	—	53	—
Ganda	40	14	15	10	3	—	42	—
English	20	13	22	10	9	4	64	68
English	21	17	19	12	4	6	52	58

TABLE II

FEMALE LUMBAR VERTEBRAL COLUMNS WITH NO BONY CHANGES AND NO SYMPTOMS

Tribe or race	Approximate age	Degrees of movement of lumbar vertebrae					Total movement (*degrees*)	
		L.5	L.4	L.3	L.2	L.1	L.2–5	L.1–5
English	20	20	12	14	9	11	55	66
English	22	22	14	17	10	0	63	63
Ganda	20	26	17	12	4	—	59	—
Ganda	20	13	24	16	11	4	64	68
Ganda	23	11	23	9	10	—	55	—
Toro	16	22	22	15	15	10	74	84

range of movement of the lumbar column. Use of the sacrum as the fixed point allows accurate analysis of the lumbar movement alone, but gives no hint of the amount of sacral movement that occurs during the rotation of the pelvis on the femoral heads during trunk flexion.

The radiographic tracings of Wiles (1935) of the lumbar spines of two normal young women demonstrate maximum total ranges of lumbar flexion and extension of 91 degrees and 81 degrees, and from Wiles's figures the pattern of movement of individual vertebrae was like that in my series. The fifth and the fourth lumbar vertebrae move most, the third less and the second and first least of all. The figures in Keegan's (1953) paper also clearly

TABLE III

MOVEMENT OF LUMBAR VERTEBRAL COLUMNS WITH EXOSTOSIS FORMATION

Tribe	Approximate age	Sex	Site of exostosis formation	Degrees of movement of lumbar vertebrae					Total movement (*degrees*)	
				L.5	L.4	L.3	L.2	L.1	L.2–5	L.1–5
Ganda	49	M	L.4	15	11	16	8	8	50	58
Soga	45	M	L.4	14	13	9	7	8	43	51
Ganda	42	M	L.4	23	5	18	12	—	58	—
Ganda	43	M	L.3, 4	17	15	12	4	9	48	57
Rwanda	50	M	L.4	22	10	7	7	2	46	48
Unknown	48	M	L.3, 4, 5	5	11	4	4	—	24	—
Teso	65	M	L.4, 5 and sacrum	0	3	18	4	—	25	—
Ganda	40	F	L.3, 4, 5	11	3	6	1	—	21	21

demonstrate the considerable mobility of the lumbar spine and that this mobility is mostly confined to the lower vertebrae.

Charnley (1951) made the surprising statement that the lumbar spine " never achieves a concavity." This may well be true of older subjects, but all the figures cited, and my own

TABLE IV

MALES WITH ACUTE BACK PAIN BUT NO BONY CHANGE

Tribe or race	Approximate age	Degrees of movement of lumbar vertebrae					Total movement (*degrees*)	
		L.5	L.4	L.3	L.2	L.1	L.2–5	L.1–5
English	40	10	0	2	6	6	18	24
Scottish	40	10	16	12	4	—	42	—
Kikuyu	26	10	4	1	2	3	17	20
Ganda	21	2	7	6	8	4	23	27

observations in subjects under about thirty years of age, show that there is always a definite anterior lumbar concavity on full flexion.

The results obtained by Charnley (1951) in his experimental study of lumbar movements differ from those found in my investigations. His results are based on artificial (manual) movement of a hemisected necropsy specimen, freed from all connection with the body. Deductions from the work of Gianturco (1944), and of Harris and Macnab (1954), show that the intact nucleus pulposus is essential for physiological movement of the spine. The

nucleus is an incompressible but mobile fulcrum about which the movement of two adjacent vertebrae occurs. On hemisection of the spine the nucleus is extruded from the cut surface by the recoil compression of the annulus fibrosus. Movement elicited under these conditions is likely to be abnormal. The movements shown by Charnley are in fact unlike the pattern seen in radiographs of living patients. In his illustration the first lumbar vertebra moves 2 degrees, L.2 moves 10 degrees, L.3 moves 11 degrees, L.4 moves 9 degrees, L.5 moves 12 degrees (compare with Table I).

CONCLUSIONS

1. Previous studies of the movements of the lumbar spine are criticised in the light of new observations from radiograph tracings. It is shown that, contrary to recent teaching, the lumbar spine is a very mobile part of the vertebral column.
2. The movement of the lumbar spine is analysed. It is shown that the lower vertebrae have the most movement, and that the range gradually becomes less in the upper lumbar spine.
3. This movement may be roughly correlated with the incidence of spurs arising from the anterior margin of the vertebral bodies.
4. These spurs are shown to arise in the anterior longitudinal ligament; they are probably caused by intermittent pressure from the intervertebral disc lying behind the ligament.

I wish to thank Dr A. G. M. Davies, Radiologist at Mulago Hospital, Kampala, and Mr W. H. Kirkaldy-Willis, Director of the Orthopaedic Centre, Nairobi, for the loan of a number of radiographs from their Departments.

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INTRAVASCULAR OSTEOCLASTS

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During the routine diagnostic examination of histological sections from a tumour of the radius (Case 1), it was observed that numerous small blood vessels contained osteoclastic giant cells like those that were present in the tumour. The blood vessels involved were situated in the connective tissues outside the periphery of the tumour (Figs. 1 to 4). The tumour was an osteoclastoma of a well differentiated type, and was classified according to the criteria suggested by Jaffe, Lichtenstein and Portis (1940) as a Grade 1 tumour.

The apparently benign nature of this tumour made it unlikely that the presence of these intravascular giant cells would adversely affect the prognosis, but at the same time it was by no means certain whether or not such a finding had previously been reported.

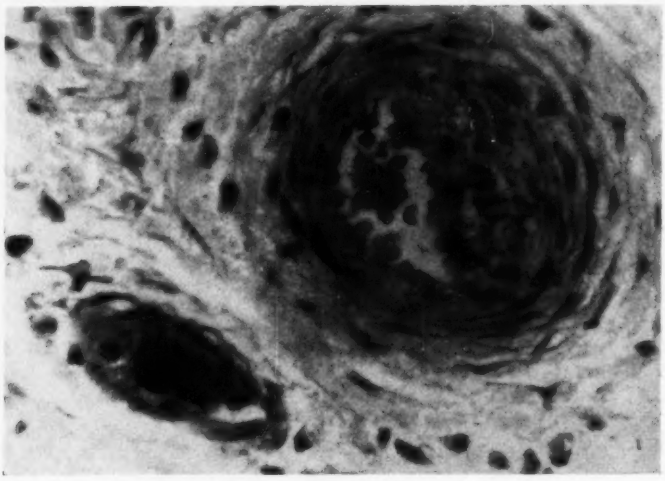

FIG. 1

Case 1—Small blood vessels outside the tumour periphery, showing an intravascular osteoclast and a half-obliterated vessel. (H. and E., ×425.)

Examination of the literature showed that, although there were some references to osteoclastic giant cells lying in " blood spaces " within osteoclastomas, there was apparently no clear description of intravascular osteoclasts in these tumours. The nearest approach to such a description was found in an account of the giant-cell tumour of bone by Harvey, Dawson and Innes (1940). These authors stated: " It is common for the multinucleated giant cells to project into apparent capillary blood spaces (Figs. 2 and 3) or even to be free in their lumen." There is, however, a qualification of this statement in the captions to these figures. Figure 3 is described thus: " Giant cell tumour of bone. Head of humerus. Same case as in Figures 1 and 2 showing multinucleated giant cells projecting into apparent spaces usually regarded as vascular, but which we interpret as probably structureless." The " spaces " referred to, and similar descriptions of " blood spaces " by other writers, may be interpreted as expressions of the loose texture and haemorrhagic nature of the stroma of osteoclastomas.

Since it seemed that no adequate description of intravascular osteoclasts had been made, it was decided to re-examine material from other cases of osteoclastoma for further evidence of the phenomenon, but at the same time it was clear that the presence of osteoclasts within blood vessels could be regarded as established only if the walls of the vessels concerned were

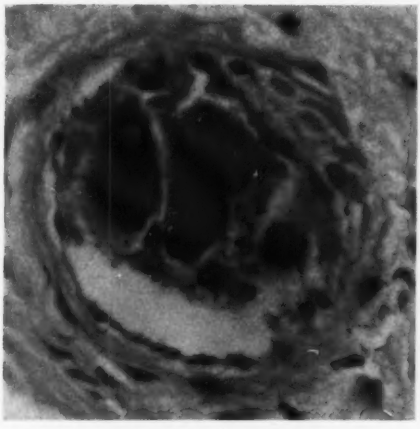

FIG. 2

FIG. 3

Case 1. Figure 2—A blood vessel containing two osteoclasts. (H. and E., ×550.)
Figure 3—A blood vessel containing a single osteoclast. (H. and E., ×350.)

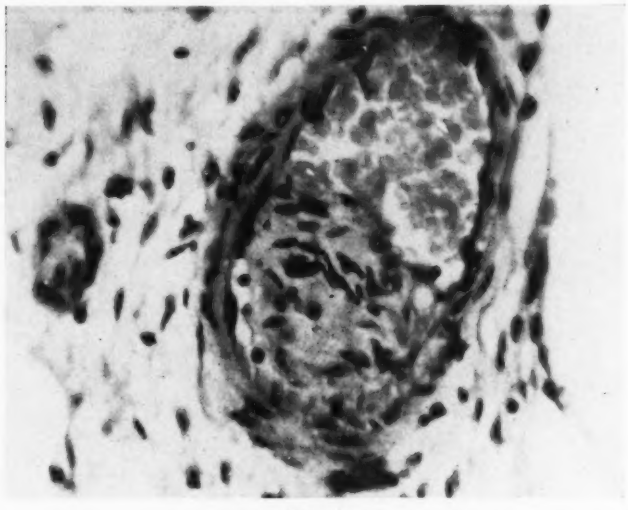

FIG. 4

Case 1—A small blood vessel lying outside the periphery of the tumour is half obliterated by the remnant of what was probably an osteoclast. There is replacement of the nuclei by nuclei of fibrocytic type. (H. and E., ×375.)

definitely identified, and if the possibility of artefactual " knife-emboli " could be excluded beyond reasonable doubt.

The examination of material from other cases of osteoclastoma was undertaken in order to investigate the following points: 1) The frequency with which intravascular osteoclasts

TABLE I

DETAILS OF THE ELEVEN CASES STUDIED

Case	Sex	Age	Site	Grade	Treatment	Follow-up	Intravascular osteoclasts
1	M	36	Distal radius	1	Excision and local radiotherapy	Well after 13 months	Numerous intravascular osteoclasts
2	M	13	Sacrum	1	Curettage and radiotherapy	Well after 4 years	No intravascular osteoclasts found
3	F	20	Proximal tibia	1	Mid-thigh amputation	Well after 13 years	One or more intravascular osteoclasts
4	M	24	Sacrum	1	Curettage and radiotherapy	Well 1 year after operation	No intravascular osteoclasts found
5	F	13	Proximal fibula	1	Excision	Well after 20 months	Protrusion of osteoclasts into blood vessels
6	F	16	Distal femur	1	Mid-thigh amputation	Well after 12 years	Protrusion of osteoclasts into blood vessels
7	M	39	Pelvis	2	Curettage and radiotherapy	Well after 3½ years	No intravascular osteoclasts found
8	F	27	Proximal tibia	2	Mid-thigh amputation	Well after 12 years	One or more intravascular osteoclasts
9	M	39	Lumbar spine	2	Curettage and radiotherapy	Well after 5 months	One or more intravascular osteoclasts
10	M	75	Calcaneum	3	Amputation	Dead 2 years later. No known metastases	No intravascular osteoclasts found
11	F	16	Distal femur	3	Amputation	Recent case	One or more intravascular osteoclasts

could be found in cases of osteoclastoma; 2) the possible modes of entry of the osteoclasts into the blood stream; 3) the fate of these intravascular giant cells; and 4) the significance of the findings in relation to histological and clinical criteria of malignancy.

MATERIAL

Eleven cases of osteoclastoma (giant-cell tumour of bone) were found in the records of the Radcliffe Infirmary, Oxford, and of the Nuffield Orthopaedic Centre (formerly the Wingfield-Morris Orthopaedic Hospital), Oxford, for the period between 1940 and 1955. This figure includes the case which has already been mentioned. Some other cases in the records were rejected because histological material from them was not available.

The sections examined were the routine ones which had been prepared for histological diagnosis. Reticulin preparations were also made when they were not already available. On the whole, however, the observations described below might have been made at any routine histological examination.

The tumours were also graded histologically according to the criteria of Jaffe *et al.* (1940).

An attempt was made to follow the progress of the various patients in whom these tumours had arisen, but in one case (Case 4) it was not possible to obtain recent information about the patient's state of health.

The details of these eleven cases are summarised in Table I. The cases are grouped according to the histological grading of the tumours, but are not otherwise arranged in any special order.

OBSERVATIONS

In five cases out of eleven, intravascular giant cells of osteoclastic type were found. In two of these five the vascular involvement was outside the periphery of the tumours (Cases 1 and 3; Figs. 1 to 5). In Case 1, as has been stated already, many vessels were affected. In the remaining four cases one, or at most two, vessels were found to be involved. The amount of tissue available for examination varied considerably from one case to another. Two of these five tumours were placed in Grade 1, two in Grade 2, and one in Grade 3.

Two further cases in Grade 1 (Cases 5 and 6) showed protrusion of osteoclasts into the blood vessels (Fig. 8), but in these cases osteoclasts were not found lying free within the blood vessels.

In the remaining four cases it was not possible to find intravascular osteoclasts. In two of these cases the histological material was fragmentary, having been obtained by drill biopsy or curettage.

It was observed that there was occasionally some inflammatory reaction around blood vessels which contained osteoclasts, when these vessels were outside the tumour periphery. There was sometimes a slightly more widespread inflammatory reaction (Fig. 5).

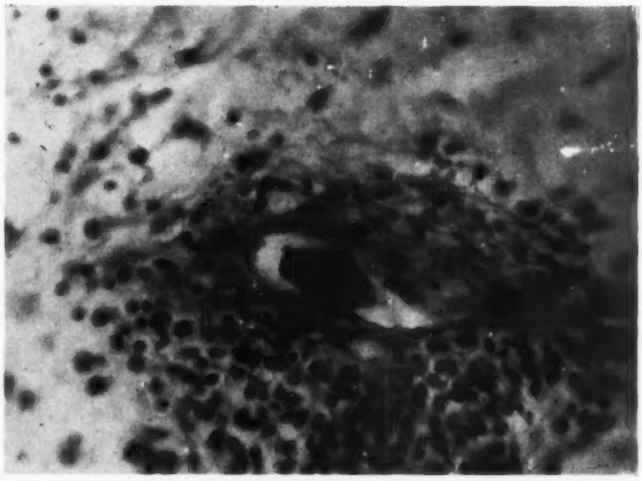

FIG. 5

Case 3—An osteoclast lying in the lumen of a small blood vessel. The vessel is lying outside the periphery of the tumour and there is a marked perivascular inflammatory reaction. (H. and E., ×340.)

Some of the blood vessels in Case 1 showed apparent impaction of osteoclasts, with subsequent degeneration of the giant cells or their replacement by fibrosis and incorporation into the vessel wall (Figs. 1 and 4). In the example shown in Figure 4 the appearance of the giant-cell remnant suggests that the nuclei of the giant cell may have undergone regression to fibrocytic nuclei, although invasion of the giant cell by fibroblasts may have taken place. The occurrence of such inflammatory reaction or fibrosis is sufficient proof that artefacts may be excluded in at least two of these cases.

In the course of these observations it was noticed that there was not infrequently some bulging of vessel walls in areas adjacent to osteoclasts. Sometimes, as in Figure 8, osteoclasts were projecting into the blood vessels although they could not be described as lying free within the vessels. In one instance there appeared to be swelling and loss of definition of the endothelial lining of the capillary wall in relation to an osteoclast which was lying outside the capillary, but which was seemingly bulging the wall of the capillary inwards (Fig. 9).

Appearances such as these suggested the possibility that osteoclasts might be capable of invading capillary blood vessels by an active process which presumably would involve the lysis or enzymatic destruction of the capillary walls. A pathway of escape into the vessels

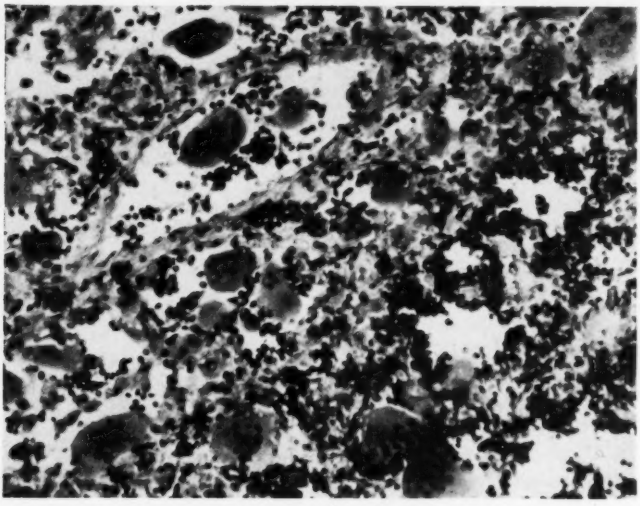

FIG. 6

Case 8—Two osteoclasts lying inside a blood vessel within the tumour. The tumour is extremely vascular and shows a considerable amount of stromal haemorrhage. (H. and E., ×210.)

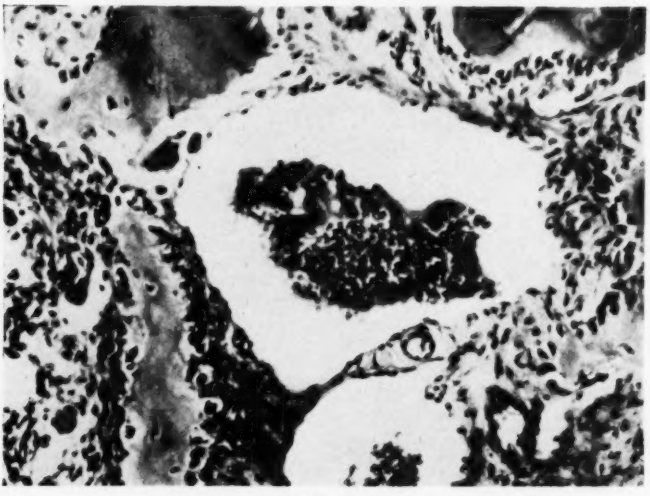

FIG. 7

Case 9—Several osteoclasts situated within a thin-walled blood sinus at the periphery of the tumour. There is reactive new bone formation in this area. (H. and E., ×210.)

would thus be opened for the osteoclasts. Some evidence in support of this theory was obtained from the study of reticulin preparations of the tumours in this series.

Figure 10 shows an osteoclast lying just outside the wall of a capillary. There appears

to be some thinning of the reticulin of the capillary wall in this region, and there is possibly slight protrusion of the cytoplasm of the osteoclast into the lumen of the vessel. A similar relationship between an osteoclast and a blood vessel is shown in Figure 11. In this case

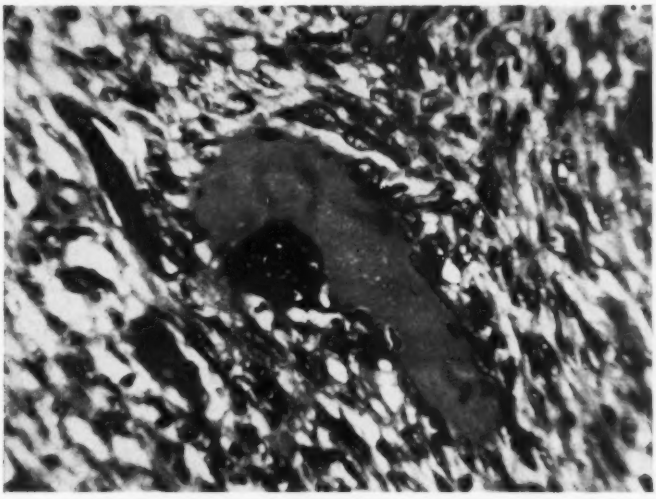

FIG. 8
Case 5—An osteoclast protruding into the lumen of a blood vessel situated within the tumour. (H. and E., ×340.)

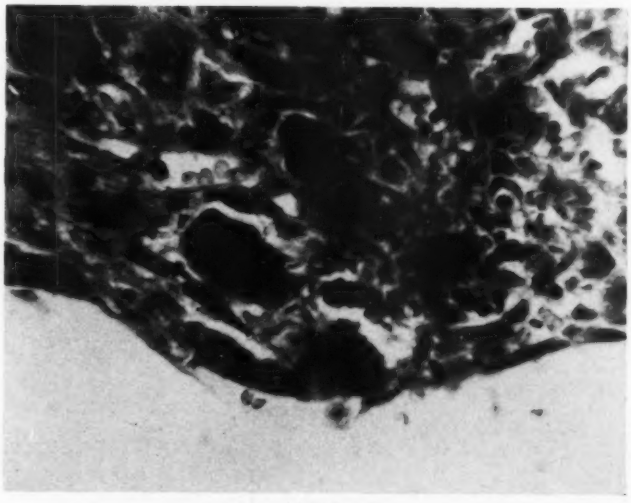

FIG. 9
Case 6—An osteoclast is shown to be lying immediately adjacent to the wall of a capillary blood vessel. The endothelial lining of the vessel is indistinct and possibly swollen where it is in contact with the osteoclast. (H. and E., ×340.)

the process of weakening of the vessel wall appears to have been carried a stage further. Along the length of capillary wall which is in contact with the osteoclast, nearly all the reticulin of the capillary wall has disintegrated, leaving only a few shreds of reticulin adherent

to the osteoclast along the line which presumably marks the former course of the blood vessel wall. Figure 8 may demonstrate a later stage in the same process.

If such a process does in fact take place, then some local action of osteoclasts upon

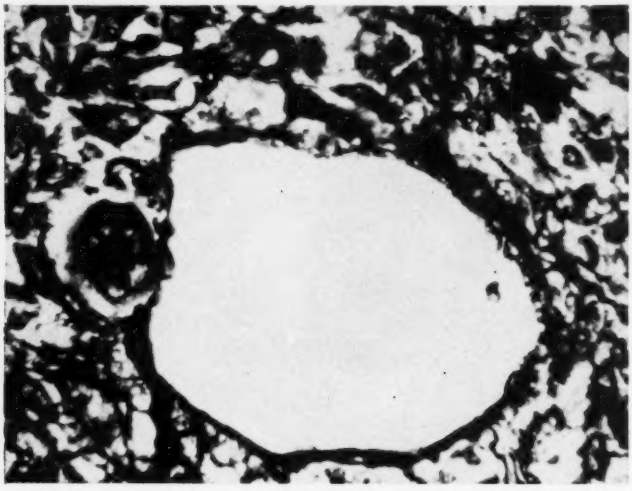

FIG. 10

Case 6—An osteoclast is shown lying close to the wall of a capillary blood vessel. There is apparent weakening of the reticulin of the capillary wall, with slight protrusion of the cytoplasm of the giant cell into the vascular lumen at one point. (Reticulin impregnation, ×600.)

FIG. 11

Case 6—An osteoclast is lying alongside a capillary blood vessel. The wall of the capillary has been interrupted immediately opposite the osteoclast, to which a few shreds of reticulin are still adherent. (Reticulin impregnation, ×500.)

the general reticulin framework of the tumours would clearly be expected to occur. A study of the reticulin pattern of the stroma of osteoclastomas shows that, in areas where reticulin fibres are running predominantly in one plane, interruption of these fibres appears to take

place in close proximity to osteoclasts. Instead of the reticulin fibres running to either side of the obstructing cell, there appears to be some breaking of the fibres and possibly some fraying of the broken ends (Fig. 12). The impression is formed that there is some local destruction of reticulin.

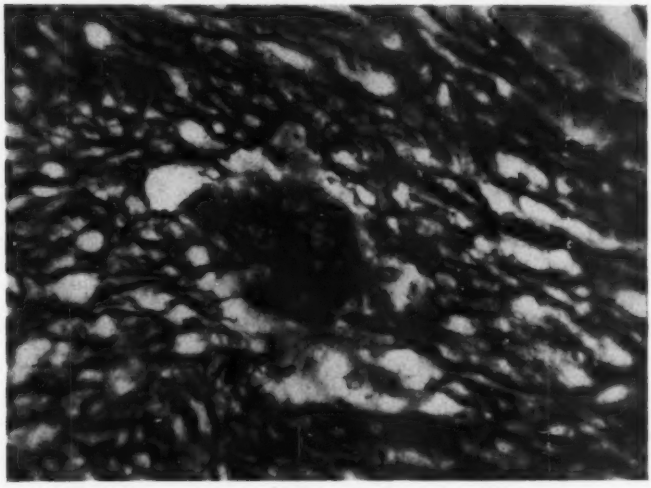

FIG. 12

Case 5—An osteoclast lying in a part of the tumour rich in reticulin fibres. These are running predominantly in a more or less horizontal plane, and show apparent interruption in the immediate vicinity of the osteoclast. (Reticulin impregnation, ×470.)

DISCUSSION

On the basis of these observations it can be stated that osteoclasts may be found with some frequency in the blood vessels traversing or immediately surrounding osteoclastomas. Their presence in these vessels does not appear to be in any way dependent upon the trauma of operation, because giant cells that had undergone considerable degrees of organisation or obliteration were found in Case 1, indicating that the process of vascular invasion had been taking place for a considerable time.

There does not appear to have been any clear description of this phenomenon in the past, although references to osteoclasts situated in, or lining, " blood spaces " are not uncommon in the literature of osteoclastomas.

Osteoclasts have not been described in the blood vessels or in the blood stream of man in conditions other than osteoclastoma, or in the normal individual. Arey (1920), however, while studying the embryos of pigs, observed and illustrated osteoclasts in blood vessels of the bone marrow. He wrote: " That such gain admittance and do not arise in situ from the endothelium is supported by their usual retrograde appearance; vacuolisation, granulation and loss of stainability of the cytoplasm, and pyknosis of the nuclei occur . . . the condition appears to indicate a method of final removal. This admission into embryonic vessels does not in itself prove or imply an amoeboid activity by the osteoclast."

Arey did not discuss the methods by which these cells might have gained admission to the blood stream. In theory there are a number of different ways by which osteoclasts might be enabled to enter blood vessels. 1) By the intravascular formation of osteoclasts as a result of the fusion of vascular endothelial cells. 2) By the following mechanism, which would require for its operation: *a*) that osteoclasts are formed by fusion of the stromal cells of

osteoclastomas; *b*) that the stromal cells of osteoclastomas are derived from vascular endothelial tissues or from cells with such potentialities; *c*) that the structure of osteoclastomas is truly sinusoidal. If all these propositions were correct, then it might be reasonable to expect that osteoclasts would find their way into the blood stream occasionally. 3) By the diapedesis of osteoclasts through intact capillary walls. 4) By the accidental escape of osteoclasts through damaged or ruptured vessel walls. 5) By the mechanism already suggested—lysis of the vascular walls, presumably as a result of enzyme activity by the adjacent osteoclasts, with the consequent escape of osteoclasts through the damaged capillary walls.

These propositions will be considered in turn.

1. It was widely held at one time that osteoclasts were derived from vascular endothelium by fusion of the endothelial cells. This view was put forward at a time when the distinction between giant cells of osteoclastic type and those of megakaryocytic type had not been established. The evidence for this origin of osteoclasts is thus rather obscure, and no convincing evidence has since been put forward in support of this theory. It may therefore be discarded, along with the theory that vacuoles in osteoclasts represent the early stages in development of vascular channels.

2. Although it is now generally agreed that tumour osteoclasts are formed by the fusion of the stromal cells of osteoclastomas, there is still no agreement about the origin of the stromal cells. Willis (1953) mentioned fibroblasts, vascular endothelium or osteoblasts as possible sources for these cells. Even if the stromal cells and osteoclasts were derived from vasoformative tissues, and there is no evidence that they are, it would still be necessary to postulate a sinusoidal structure in these tumours to explain the entry of osteoclasts into the circulation. On the contrary, although these tumours are often very vascular, vessel walls can usually be identified, and the blood which is found in the stroma is present there in all probability as a result of haemorrhage.

3. The osteoclast is not known to be capable of amoeboid movement, and it is unlikely to be capable of diapedesis. Furthermore, it is an extremely large cell, especially in the pathological forms found in osteoclastomas. For this reason alone it would almost certainly be incapable of passing through the interstices of an undamaged capillary wall.

4. It is possible that osteoclasts may gain admission to the circulation as a result of damage to capillary walls which, in these tumours, are often very thin. Although the osteoclast is a large cell, certain conditions of trauma might allow it to enter the blood vessels. Even larger fragments of bone marrow may be found in the lungs after fractures and convulsions (Tierney 1952), and amniotic emboli are often of considerable size (Steiner and Lushbaugh 1941), although in the case of the latter there are special factors of muscular pressure and vascular structure to be taken into consideration.

One cell that is comparable in size with the osteoclast is the megakaryocyte. This cell has been found in the lungs in as many as 56 per cent of patients who died suddenly from various causes, and up to 100 per cent of patients with acute bacterial encarditis showed megakaryocytes in the pulmonary capillaries (Seebach and Kernohan 1952). It is not surprising, however, that megakaryocytes should enter the circulation, together with other immature haemopoietic cells, in conditions of acute physiological stress or even under more normal conditions.

Other benign conditions in which pulmonary intravascular deposits may be found are normal pregnancy and invasive hydatidiform mole. The presence of chorionic tissue in the circulation may be due primarily to the invasive powers of this tissue rather than to traumatic factors.

Vascular invasion is not a feature of other benign tumours, but it is possible that the relatively delicate vascular structure of osteoclastomas may predispose to the entry of osteoclasts into the circulation as a result of trauma. This possibility cannot be excluded from consideration.

5. The observations that have been described above suggest that one mechanism by which osteoclasts enter the blood stream entails an active lysis of the vessel walls by osteoclasts. This process could be brought about by enzyme activity on the part of the osteoclasts.

Although the evidence that has been put forward in support of this possibility might seem slender, it must be remembered that there is no general agreement on the way in which normal osteoclasts assist in the resorption of bone, in spite of a considerable amount of observation and experiment which has been made in this field.

Some workers have maintained that bone destruction is the result of an osteolytic process, and that the osteoclasts serve a phagocytic purpose. This theory has been upheld by several authors, including Leriche and Policard (1928).

Others regard the osteoclast as the prime mover in the process of absorption, but while some (Jaffe *et al.* 1940) regarded it as a phagocytic cell in this connection, Willis (1953) denied that the osteoclast was a skeletal phagocyte.

It is thought that, whatever the exact mechanism of bone resorption may be, the collagenous matrix of bone, the ground substance and the bone salts that lie upon the matrix are all removed simultaneously in the process. It has recently been claimed that a limited process of halisteresis takes place and that the ends of collagen fibrils may be seen protruding from the surface of the bone that is undergoing resorption (Ham and Gordon 1952).

Kroon (1954) considered that osteoclasts were actively concerned in the process of bone resorption and claimed to have shown that the striated borders of osteoclasts (Kölliker's brush borders) were formed by the penetration of protoplasmic projections from the osteoclast into the bone substance; the bone substance trapped in the border was broken down and liquefied in vacuoles, which increased in number during the process.

It is perhaps also of significance that Kroon described the way in which argyrophil (reticulin) fibrils of the extracellular structure of the bone might be seen protruding regularly like teeth from the bone substance into the striated border. These fibrils he described as being suddenly broken down in the border of the osteoclast and disintegrating into black granules.

If the action of osteoclasts in the resorption of bone is accepted as a positive process, probably requiring some enzyme activity on the part of the cell, there is no great difficulty in visualising a process of slow absorption of capillary walls adjacent to the osteoclasts, with subsequent escape of the osteoclasts through the gaps thus created. The action of the osteoclasts would probably be confined to an area within a very short distance from the cell.

The formation of large holes in the walls of blood vessels would perhaps help to explain, in part at any rate, the areas of haemorrhage that are not infrequently found in the stroma of osteoclastomas.

All three histological grades of malignancy were represented among the cases in which intravascular osteoclasts were found. Of the two patients with tumours of Grade 1, one has lived for just over a year with no sign of tumour recurrence after excision and local radiotherapy. The other was treated by amputation thirteen years ago, and the patient has recently written to say that she is in excellent health.

There were two tumours in Grade 2 in which intravascular osteoclasts were found. One of the patients was well twelve years after her leg had been amputated; the other was treated by curettage and discharged from hospital fifteen months ago. There is no recent information about his progress.

The fifth tumour was placed in Grade 3. This patient had a leg amputated six months ago and so far has remained in good health.

Two tumours, in which there was protrusion of osteoclasts into blood vessels, without evidence of complete vascular invasion, were placed in Grade 1. One patient was well twenty months after the local excision of the tumour, the other has remained well for twelve years after amputation of a leg.

From these facts it seems probable that the presence of osteoclasts in the blood stream is not related to the grade of malignancy of the tumour. It must also be assumed that in at least some of these cases there was more widespread dissemination of osteoclasts than the sections indicated, without serious consequences to the patients.

The presence or absence of intravascular osteoclasts in an osteoclastoma should not, therefore, be taken into account in assessing the histological grade of such a tumour. The cellular morphology of the stroma, the degree of pleomorphism, mitotic activity, and the other features stressed by Jaffe *et al.* (1940), are of more importance.

The osteoclastoma may, however, be placed alongside the invasive hydatidiform mole as an example of a benign tumour which is capable of vascular invasion without the subsequent development of metastatic deposits. The suggested method of entry of osteoclasts seems unlikely to bear any relationship to the methods employed by the cells of hydatidiform mole or by the cells of malignant tumours, except in so far as enzymes may play a part in some or all of these processes.

It should be pointed out, however, that emboli of malignant tissue from other types of tumours may be found in the pulmonary blood vessels without their having given rise to metastatic deposits.

Saphir (1947) has confirmed the earlier claims of Iwasaki (1915) that tumour emboli may be made innocuous by a process of organisation, and suggests that organisation is initiated by the formation of hyaline thrombi around the emboli. The eventual intimal thickening closely resembles pulmonary arteriosclerosis.

The fate of these intravascular osteoclasts is uncertain. It appears, from the material obtained in Case 1, that some of the cells become impacted in the smaller blood vessels and are eventually incorporated into the vessel walls by a process of fibrous organisation from without. The possibility also exists that the osteoclastic nuclei retain the power of reverting to fibrocytic nuclei.

It is presumed that other osteoclasts are carried away in the general circulation and are filtered off in the capillary bed of the lungs, or that, if they succeed in passing through the lungs, they meet a similar fate elsewhere.

Only if they are derived from a malignant tumour will the osteoclasts, or the isolated stromal cells which must occasionally accompany them, possess the requisite powers of independent proliferation to form secondary deposits of tumour tissue. Even then, many of the cell emboli may be rendered harmless by the processes described above. It is not known whether any increase in malignant potentiality in the tumour is accompanied by an increased or a decreased tendency for osteoclasts to invade blood vessels.

SUMMARY

1. In five out of eleven cases of osteoclastoma it was found that osteoclasts were present inside clearly defined blood vessels either within the tumours or in the tissues immediately surrounding the tumours. In two further cases it was found that osteoclasts protruded into the vessels although they were not lying free within the vessels.

2. The possible modes of entry of these cells into the blood stream are discussed. Although accidental dissemination of osteoclasts into damaged blood vessels could not be excluded, it was felt that the process was equally likely to be related to some inherent property of the osteoclasts. From further observations it is suggested that osteoclasts are capable of local destruction of the connective tissues of the vessel walls, probably by enzyme action. Such an action might be analogous to the processes by which, in the opinion of many, osteoclasts bring about the resorption of bone.

3. There did not seem to be any relationship between the finding of intravascular osteoclasts and the malignancy of the tumour, assessing the latter either on histological or clinical grounds.

The finding of intravascular osteoclasts does not therefore appear to be of any prognostic significance.

I am grateful to physicians and surgeons of the Nuffield Orthopaedic Centre (formerly the Wingfield-Morris Orthopaedic Hospital) and the United Oxford Hospitals for permission to include details of patients who have been under their care. I wish to thank Dr A. H. T. Robb-Smith for much helpful advice in the writing of this paper, and Mr A. Mann and Mr M. Morris for assistance with the photography.

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THE NORMAL VASCULAR ANATOMY OF THE HUMAN FEMORAL HEAD DURING GROWTH

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The vascular pattern of the head and neck of the adult human femur has already been published as part of an investigation on the circulation in the normal and in some pathological conditions of the hip joint (Trueta and Harrison 1953). Soon after this work was begun it appeared convenient to investigate the changes in the vascular arrangement of the upper end of the femur in the period between birth and epiphysial maturation.

The need for a definite understanding of the vascular structures during growth seems too obvious to need any elaboration here: it is believed that many of the disorders occurring in the hip, and particularly in the femoral head, during growth are of vascular origin, including Perthes' disease, infantile coxa vara, osteochondritis dissecans and slipped epiphysis.

Yet, in spite of the repeated efforts to elucidate this relationship, there is some confusion as to the particular importance of each of the individual arterial systems which penetrate the femoral head and neck at any particular time. If further evidence is needed it may suffice to consider the role that has been attributed to the vessels of the ligamentum teres from the time when Hyrtl (1846) mentioned that the round ligament in children had vessels that did not enter the femoral head, a belief which denied the contention by Palletta (1820) that these vessels played an important part in supplying the femoral head. This has been, however, repeatedly denied (Schmorl 1924, Nussbaum 1924, Elgart 1927); and Jones and Lovett (1929) summarised the current views on this particular subject, stating that it had been " conclusively shown that the few vessels present in early life supply a small zone of articular cartilage only. In the adult the ligament is an avascular structure." Others thought that the vessels of the ligamentum teres, present in the very young, gradually decreased in importance (Kolodny 1925) or ceased altogether to be permeable after fusion of the epiphysis (Zemansky and Lippman 1929), whereas Wolcott (1943) and others thought that the vessels of the ligamentum teres did not become patent until after fusion.

A number of more recent works have attempted to throw light on this problem (Latarjet and Trillat 1935, Cheynel 1947, Tucker 1949, Etienne and Granel 1949, Howe, Lacey and Schwartz 1950), but so far as I am aware no work has been published recording the changes in vascular pattern of the upper end of the human femur in an orderly sequence from the foetus to adult life. Neither is there a work that analyses these changes without the use of drawings and other subjective methods of recording data.

The present paper is an attempt to explain the evolution of the vasculature of the head and neck of the human femur from the last four weeks of foetal life up to the fusion of the upper femoral epiphysis at the age of seventeen. I have left aside for the time being the description of the vascular arrangement of the human embryo, as this investigation is still in progress and some gaps in our information must be bridged before the work is ready for publication. To emphasise the difficulties encountered in this work and the necessity for caution in reaching conclusions it may be mentioned that although we have been collecting data for the last seven years the information available is by no means complete. A number of specimens could not be used because there was some defect in the injection or in the preparation of the specimen.

MATERIAL AND METHODS

This investigation refers exclusively to human specimens removed after death and injected with the technique described elsewhere (Trueta and Harrison 1953). The material used for this study is given in Table I. It will be noted that the two sexes have been kept apart and are shown in different columns. This was done with the purpose of detecting any change that may become apparent, particularly at the age of maturation, and may manifest differently in the two sexes. As will be seen later, no clear evidence was available up to about fourteen years of age to indicate the sex to which the specimen belonged.

Altogether forty-six specimens of the upper end of the femur were available, after those which for one reason or another were considered unsuitable for this study had been discarded. This number of good specimens might have been considered sufficient but for the irregular

TABLE I

MATERIAL AVAILABLE FOR STUDY

Age of subject at time of death	Number of femoral heads	
	Male	Female
From end of foetal life to 6 months	6	5
6 to 12 months	2	0
1 to 2 years	3	2
2 to 3 years	0	5
3 to 4 years	0	4
4 to 5 years	2	1
5 to 7 years	3	0
9 to 10 years	1	0
10 to 11 years	0	1
11 to 12 years	1	1
12 to 13 years	0	1
13 to 14 years	2	2
14 to 15 years	1	0
16 to 17 years	0	3
	21	25

age distribution of our material: twenty-three specimens covered the period from the last three weeks of foetal life until three years of age, and ten the following three-year period, whereas only one injected specimen was available for the period of six to nine years of age. Twelve injected femoral heads were available for the study of the vessels during adolescence. Some caution seems advisable in the interpretation of our findings, at least until they are confirmed by further work.

All the injected specimens were from cadavera of children of white Western European stock. Most came from hospitals in Oxford and London, but nine were from Barcelona and Oporto.

Neoprene Latex injections were not used in this investigation because it was considered that they could not provide better and more reliable information than either the transparency

technique of Spalteholz after injection of 2 per cent solution of Prussian Blue, or micro-radiography after injection of barium sulphate suspension (Micropaque).

For the study of the smaller vessels I have adhered to the methods described in previous work (Trueta and Harrison 1953).

FIG. 1
Radiograph of femur of a newly born infant.

RESULTS

Vascular arrangement at birth—Before the vasculature of the upper end of the femur at birth is described, it is convenient to remember that the process of ossification, initiated in the centre of the shaft in the middle of foetal life, has now reached the area which will later become the femoral neck and greater trochanter (Fig. 1).

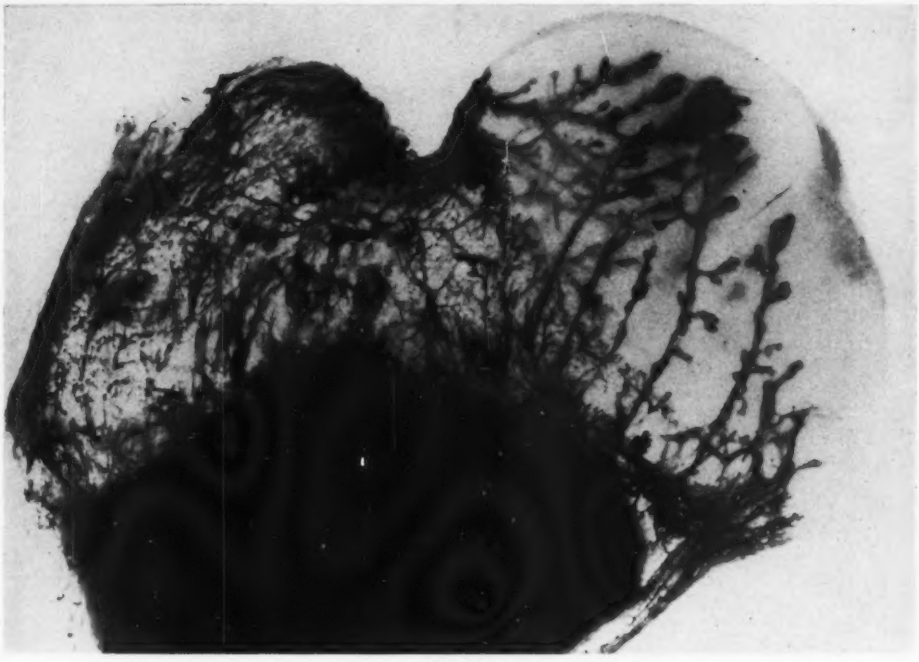

FIG. 2

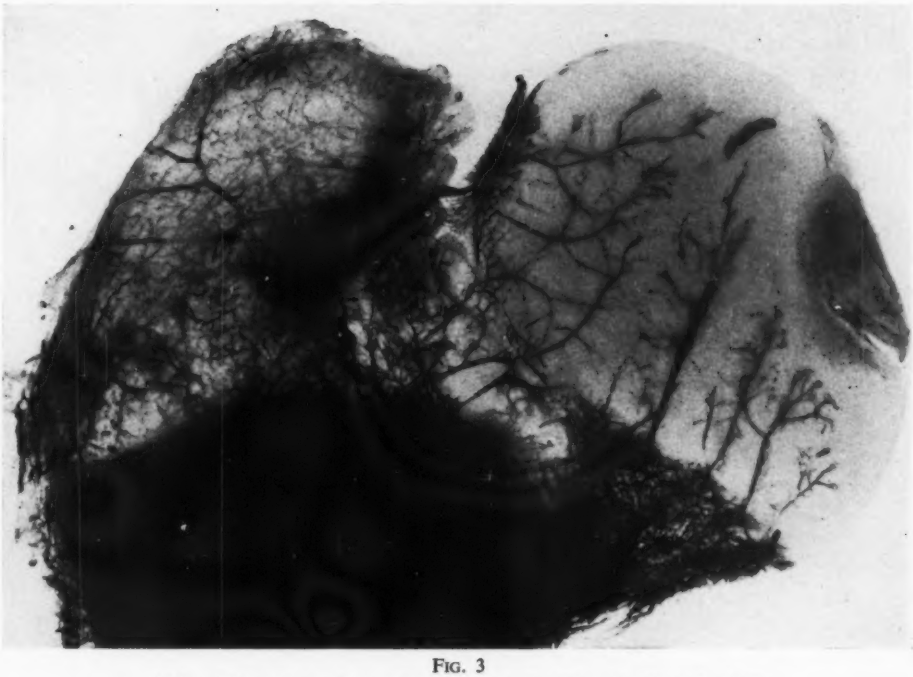

FIG. 3

Male, eighteen days. Figure 2—Anterior half. Figure 3—Posterior half.

FIG. 4

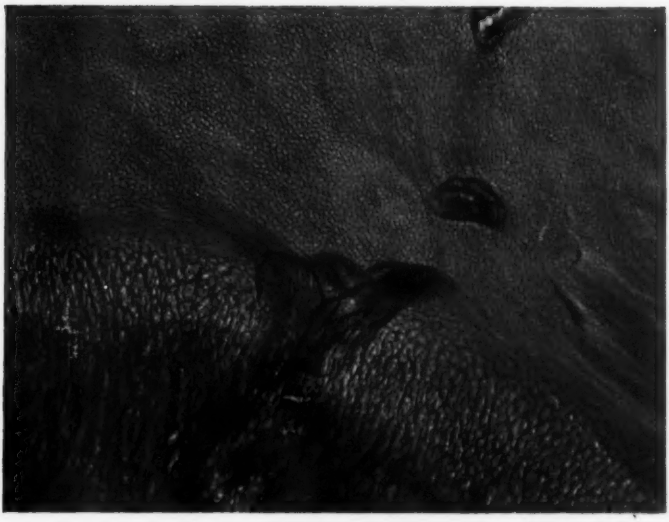

FIG. 5

Female, two months. Figure 4—Thin section showing the ascending vessels penetrating the layers of cartilaginous cells which later will constitute the epiphysial plate. Figure 5—Magnification of the area illustrated in Figure 4.

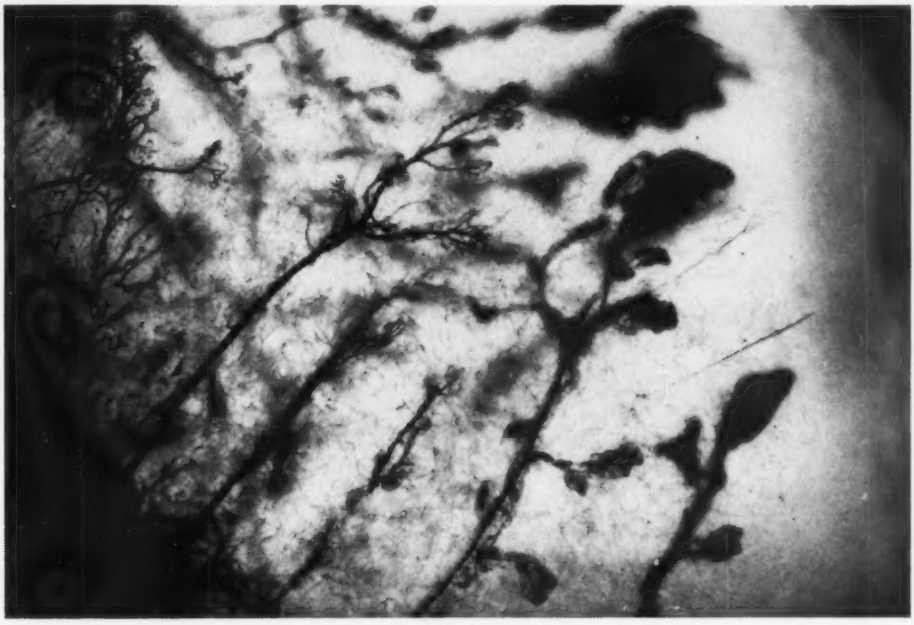

FIG. 6

Female, three months. Metaphysial vessels ascending almost vertically towards the higher part of the femoral head.

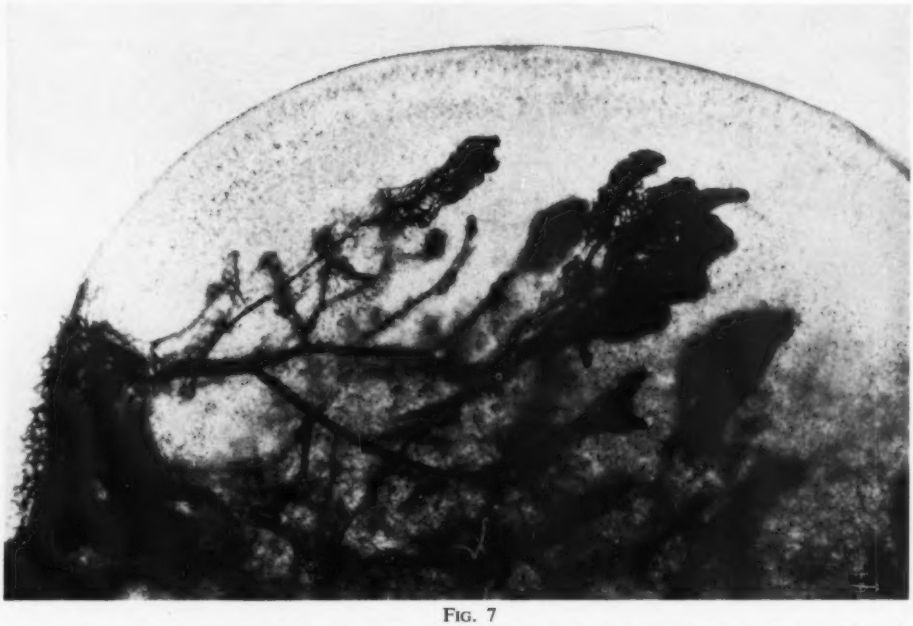

FIG. 7

Female, three months. Lateral epiphysial vessels penetrating almost horizontally across the femoral head.

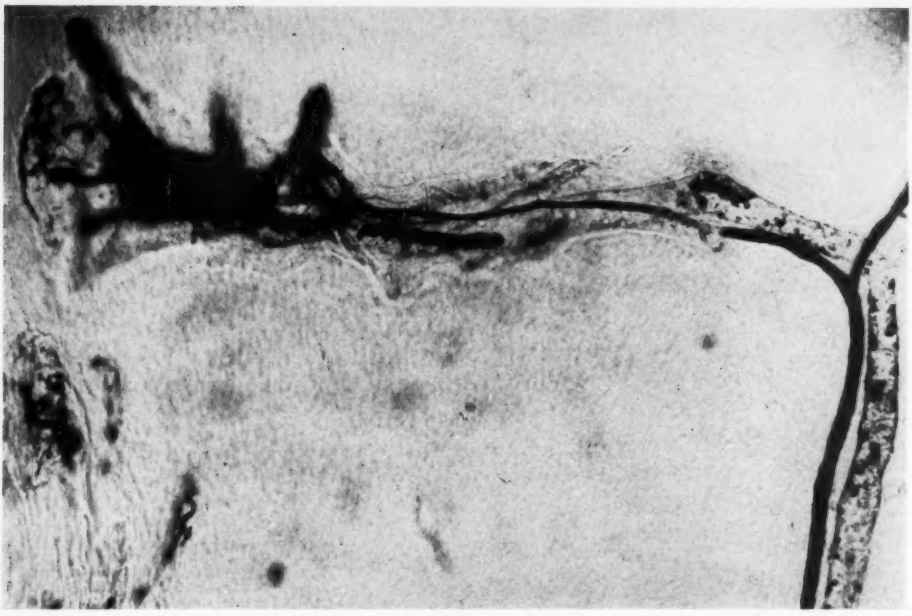

FIG. 8

Female, three months. Artery penetrating the cartilaginous head accompanied by its vein with their terminal net-like expansions. (×75.)

The vascular pattern at this stage is one of the most constant that I have found. From the top of the ossifying border a series of straight vessels, varying in number from ten to fifteen, ascend almost vertically through the cartilaginous head (Figs. 2 and 3). They emerge principally from the medial side of the metaphysis after crossing the layers of cartilaginous cells which later will constitute the epiphysial growth plate (Figs. 4 and 5). They proceed towards the top of the head, ending at a definite distance from the surface (Fig. 6). Another large group of vessels enters the outer part of the femoral head, in the region of the trochanteric notch, and advances horizontally, descending slightly towards the centre of the head (Fig. 7). They are thus at approximately 90 degrees from the previously described metaphysial vessels. These two systems of capital vessels will, once the epiphysis is finally organised, constitute the inferior metaphysial and lateral epiphysial vessels respectively which we have described elsewhere (Trueta and Harrison 1953). The most intriguing feature of all these vessels is their ending: every artery nearing its termination breaks into a number of pre-capillaries and capillaries with shapes like the spray of a fountain, soon to join up again into a single large vein which runs back in close contact with its artery (Figs. 8 to 11).

Whatever the function of these terminal arrangements may be, they seem related to the preparation of the endochondral head for ossification. At sufficient magnification (Fig. 12) the young cartilaginous tissue surrounding them takes on a granular appearance.

The behaviour of the vessels entering the ligamentum teres is of interest. In late foetal and early neo-natal life it is common to find a large artery with some smaller vessels entering the femoral head and distributing themselves through an area approximately as large as the one we found in later life (Trueta and Harrison 1953). After a perfect injection it is seen that the arteries from the round ligament penetrate even further the cartilaginous head and drain into fine veins. Each of the terminal capillaries is of the same length, a curious arrangement

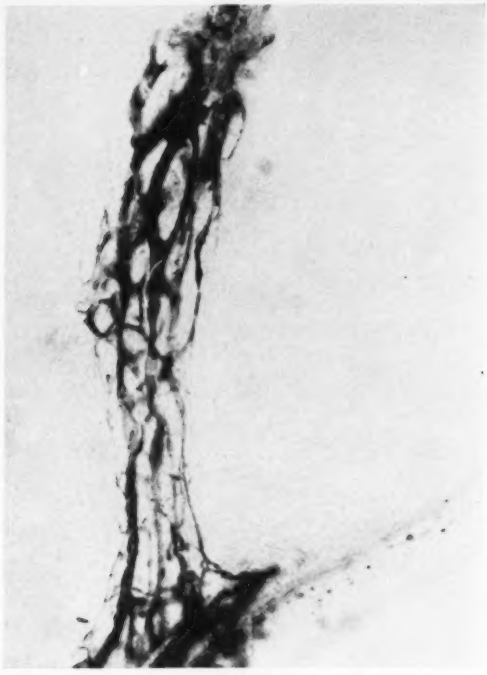

FIG. 9
Female, three months. The venous network is here longer and overshadows the artery. (×90.)

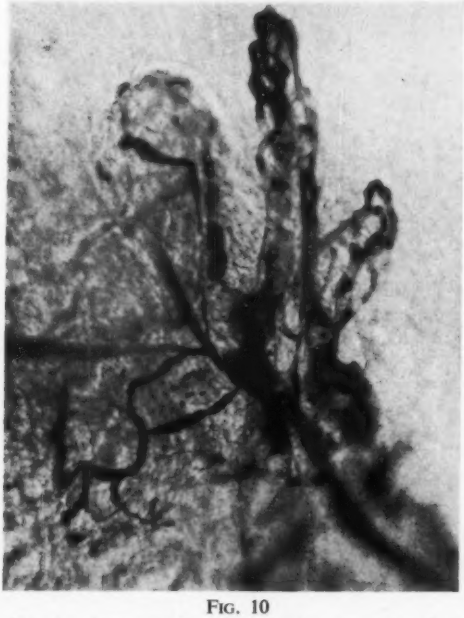

FIG. 10

FIG. 11
Female, three months. Two further examples of the terminal vascular arrangement. (Figure 10, ×140; Figure 11, ×90.)

which gives to this vascular area the shape of a daisy (Figs. 13 and 14). No connection whatsoever has been found at this early stage of pre-natal and post-natal development between the three vascular systems of the femoral head, each artery ending in a venous lake which frequently appears like a laurel leaf.

FIG. 12

Female, three months. The sinusoid type of vascular ending with an artery opening into the venous network. Note the granular nature of the cartilaginous ground substance surrounding the vessels.

Vascular pattern from four months to three years—The most appreciable change in the vascular arrangement occurring before the fourth month is the disappearance of the penetrating vessels from the ligamentum teres. This coincides approximately with the time when the secondary ossification centre is first seen in the middle of the femoral head. Usually the ossicle is single, but on occasions it begins with several nuclei, the largest of which is in the middle (Fig. 15). On section the main points of vascular penetration, both metaphysial and lateral epiphysial, are well seen (Figs. 16 and 17).

FIG. 13

Foetus. Microradiograph showing the penetration of large arteries from ligamentum teres into the cartilaginous head.

FIG. 14

Example of penetrating capillaries in another foetal femoral head from the arteries of the ligamentum teres.

From four to eight months the ossifying centre has grown to occupy the middle third of the cartilaginous head (Fig. 18). After decalcification the injected specimen shows a rich vascularity of the ossicle and sometimes vessels of the ligamentum teres which do not penetrate the bony nucleus (Figs. 19 and 20).

The organisation of the secondary nucleus of ossification steadily progresses, and at eighteen months the epiphysis is well constituted, even if the space of the epiphysial cartilage

FIG. 15
Male, four months. Fragmented ossicle of secondary ossification.

is still large (Fig. 21). With the specimen decalcified (Figs. 22 to 24) a new feature, already initiated some months earlier, is now clearly outlined—namely that the main source of blood supply to the epiphysis at this stage, if not as yet the only one, comes from the vessels we have called in the adult the lateral epiphysial arteries. The foetal ascending metaphysial arteries are rapidly decreasing in number and calibre and are now entering the epiphysis

FIG. 16

Male, four months. Section showing the centre of secondary ossification and several canals of vascularisation penetrating both from the metaphysis and lateral side of the epiphysis.

FIG. 17

Male, four months (same specimen as Figure 16). Microradiograph after decalcification of the whole head showing the actual vessels whose sectional canal is shown in Figure 16. No round ligament vessels are seen at this age.

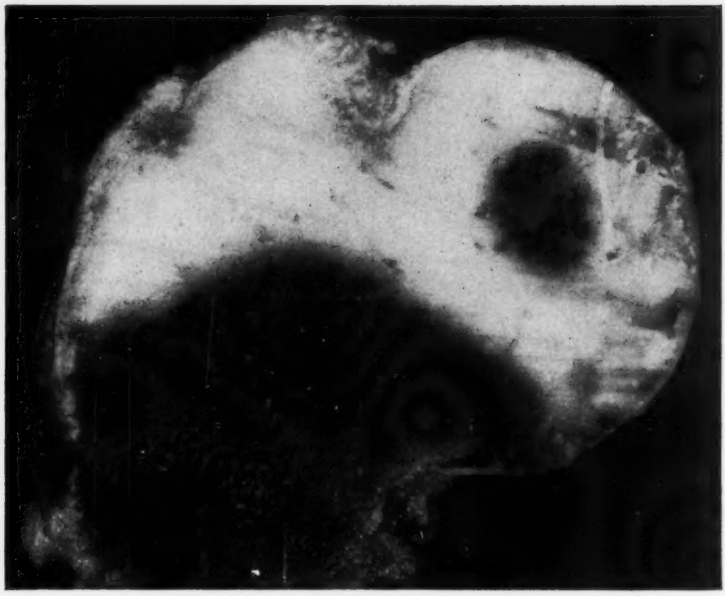

FIG. 18

Male, eight months. Photograph of the cartilaginous head with the secondary centre of ossification occupying approximately the middle third of the femoral head. At this period of development the metaphysis facing the head is almost as large as that facing the cartilaginous trochanter.

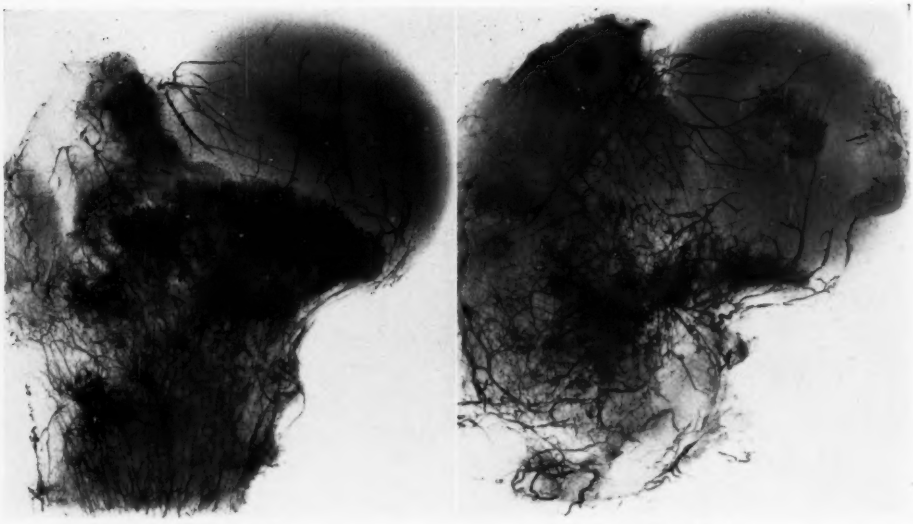

FIG. 19 FIG. 20

Male, eight months. Decalcified anterior half (Fig. 19) and posterior half (Fig. 20), showing the size and profusion of metaphysial vessels penetrating the femoral head and some vascularisation of the round ligament, which is not connected with the ossifying centre.

FIG. 21

Female, eighteen months. Radiograph showing the large size of the ossified capital epiphysis. No nucleus of ossification yet appears in the cartilaginous trochanter.

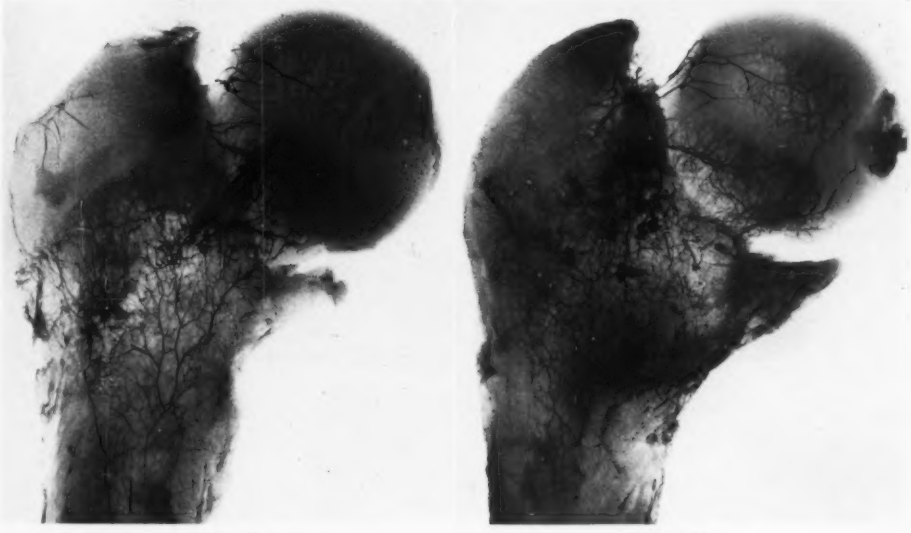

FIG. 22

FIG. 23

Female, eighteen months. Microradiograph of anterior half (Fig. 22) and posterior half (Fig. 23), showing at this stage the predominance of the lateral epiphysial vessels over the metaphysial. Note the lack of vessels from the ligamentum teres.

after crossing the outer perimeter of the growth plate; they no longer pierce the epiphysial cartilage as was the case earlier.

The tendency towards an exclusive lateral epiphysial circulation continues, even if substantial and individual variations are frequent (Figs. 25 to 27). But now and for the following three, or sometimes four, years the arteries of the ligamentum teres are either

FIG. 24

Female, eighteen months. Photograph of Spalteholz preparation of the same specimen as that shown in Figures 22 and 23.

totally absent (Figs. 28 to 30) or they reappear but do not penetrate even the cartilage of the foveal region (Figs. 31 to 33).

At three years of age the metaphysial vessels have usually diminished still further, although they may not have completely disappeared (Figs. 34 to 36). At four years the arteries from the ligamentum teres are usually patent, but they do not contribute to the supply of the epiphysis, although insufficient observation may lead to error (Figs. 37 and 38).

The intermediate vascular pattern—At this stage of the vascular development the intermediate period of childhood is reached, with marked individual and racial variations. This is characterised by the complete organisation of the bony epiphysis with only one source of blood, that coming from the lateral epiphysial vessels, which are branches of the distal part of the medial circumflex artery. Figures 38 and 39 show a good example of the vascular

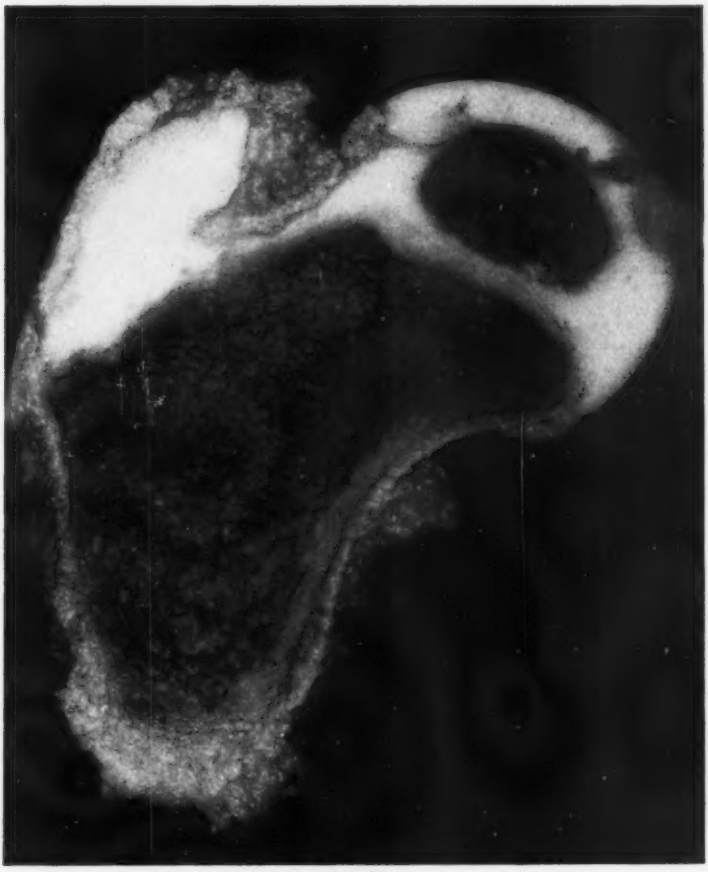

FIG. 25

Female, twenty-one months. Photograph of a section showing a progressive lengthening of the femoral neck and a reduction of the area occupied by the growth cartilage of the femoral head.

arrangement at four years of age. The points of entry of the lateral epiphysial arteries are close together in the outer segment of the head, and slightly posterior. A minute metaphysial artery still reaches the epiphysis in its medial side, and a number of large arteries in the ligamentum teres end without any connection with the epiphysis. Before six years of age the same arrangement is found, but occasionally an exceptionally well supplied epiphysis is seen, like that shown in Figures 40 to 42, where (in Figure 42) an artery of the ligamentum teres has already penetrated the epiphysis, anastomosing with the rest of the vascular tree

FIG. 26

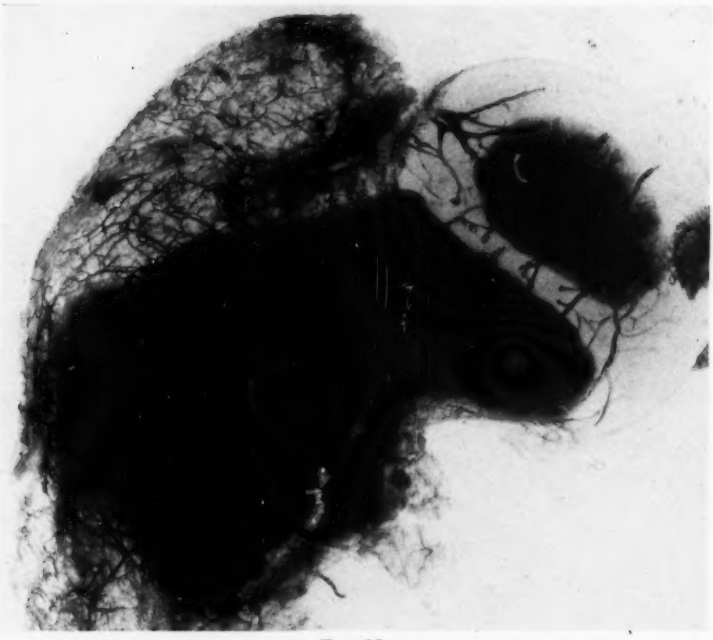

FIG. 27

Female, twenty-one months. Photographs of Spalteholz preparation. Figure 26—Anterior half. Figure 27—Posterior half. This femoral head shows a much more profuse metaphysial vascularisation than that shown in Figures 22 to 24. Round ligament vessels are also visible.

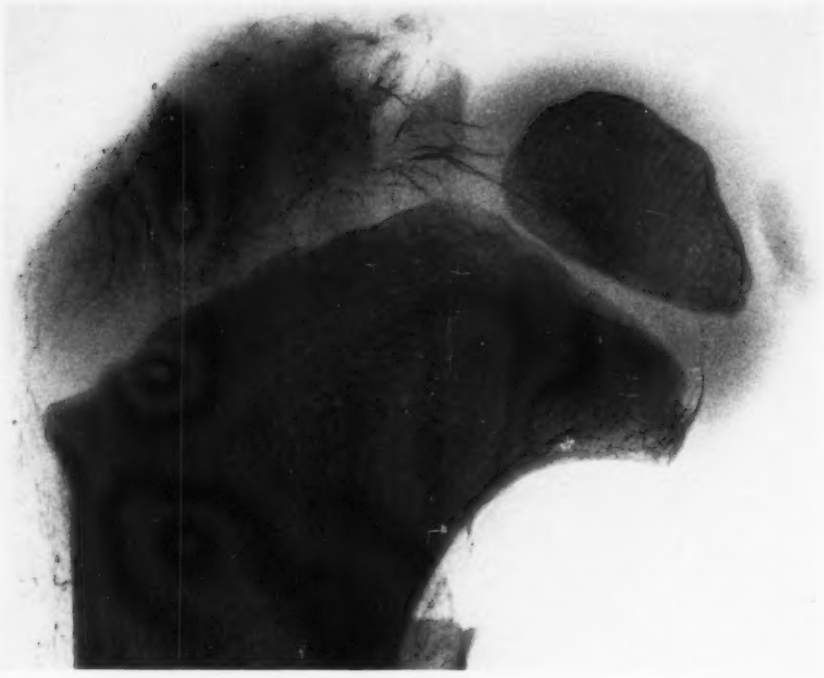

FIG. 28

Male, two years and six months. Radiograph showing the absence of round ligament arteries and further increase of the ossifying femoral neck.

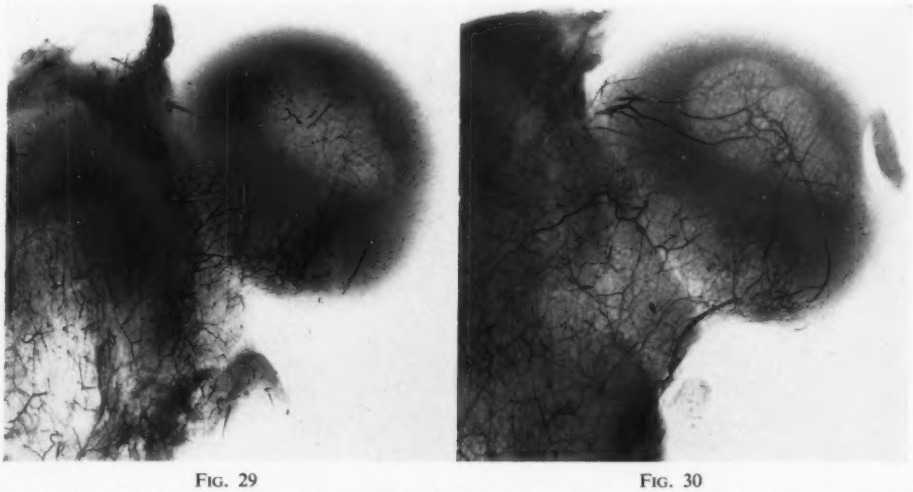

FIG. 29 FIG. 30

Male, two years and six months. Microradiograph of decalcified anterior half (Fig. 29) and posterior half (Fig. 30) showing the lateral epiphysial vessels anastomosing with three remaining metaphysial vessels which cross over the epiphysial plate.

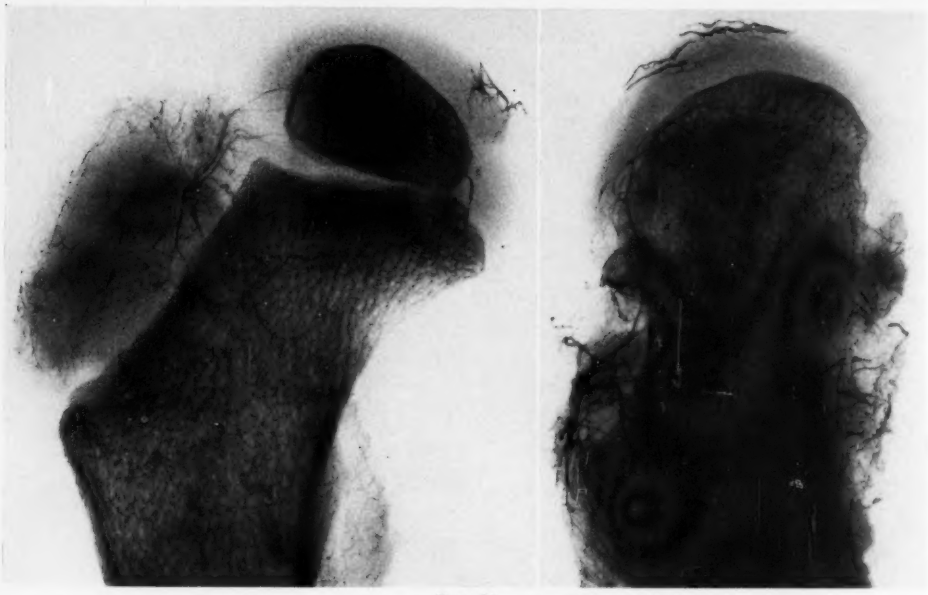

FIG. 31

Female, two years and ten months. Antero-posterior and lateral radiographs demonstrating the lack of penetration of round ligament arteries at this age. Note the increase in length of the metaphysis of the femoral neck facing the trochanter, which has not yet begun to ossify.

FIG. 32

FIG. 33

Female, two years and ten months. Microradiographs of decalcified anterior half (Fig. 32) and posterior half (Fig. 33). Two or three metaphysial arteries penetrate the capital ossicle while arteries from the ligamentum teres remain unconnected.

while some of the infantile metaphysial vessels still remain. Apparently, this is an arrangement that protects the nourishment of the epiphysis during the transient intermediate period which extends from four to seven years. More commonly the distribution of the metaphysial arteries at about six years of age is like that of the adolescent, when they have finally disappeared, but the infantile absence of blood flow from the ligamentum teres still persists. Figures 43 to 45 show good examples of this intermediate vascular pattern.

FIG. 34

Female, three years. Radiograph showing further lengthening of femoral neck and narrowing of the area occupied by the epiphysial plate.

The pre-adolescent period—From the age of seven upwards the penetration of vessels from the ligamentum teres appears to be increasingly frequent, and at nine or ten the pre-adolescent type of epiphysial blood supply seems definitely established, even if sometimes the participation of the medial epiphysial arteries does not seem so great as in adult life (Fig. 46). The growth plate is an isolating barrier raised between the femoral epiphysis and the rest of the bone, as is well seen in Figures 47 and 48 (obtained from a boy eleven years of age) and in Figures 49 and 50, where a female head of thirteen years shows the clear-cut division of the two vascular systems which will continue until epiphysial fusion is complete.

The adolescent period—It is to be noted that, even at puberty, the infantile unity of the epiphysial plate of the upper end of the femur still persists, as shown in Figures 51 to 54 where a single epiphysial cartilage covers the whole of the neck under the epiphyses of the head and greater trochanter. By then the growth plate corresponding to the head may begin to show the first signs of its imminent disappearance (Figs. 55 and 56).

FIG. 35

FIG. 36

Female, three years. Microradiograph of anterior half (Fig. 35) and posterior half (Fig. 36). The number and calibre of the metaphysial vessels have further diminished. No connection is yet established between the ligamentum teres vessels and those in the ossifying centre.

A rich vascularity is frequent at the upper part of the metaphysis at this age, whereas the side of the epiphysis covering the growth plate does not show any corresponding vascular profusion. It may be that this is the vascular pattern preceding epiphysial fusion, when cartilage cell proliferation begins to decrease and ossification progresses from the metaphysial side towards the epiphysis until the whole area of the growth cartilage becomes ossified. The importance of the vessels from the ligamentum teres is obvious at this stage.

Closure of the space occupied by the growth cartilage after this age is well on the way, and at seventeen it was found complete in the three different heads examined. Figures 57 and 58 show the upper femoral epiphysis of a girl of seventeen years with many anastomoses

FIG. 37

Female, four years. Radiograph showing the penetration of an artery from the ligamentum teres into the femoral head. After decalcification this was shown to be an error. A shadow produced by the centre of ossification in the trochanteric region is seen.

joining the epiphysial with the metaphysial vessels, an arrangement that will be present throughout life. This was also found to be the case with the vessels of the ligamentum teres, an observation that corroborates the findings in our previous work.

The vessels adjoining the epiphysial plate—For the study of these vessels we have used sections of particularly well injected specimens, a small selection of which illustrates our main findings. In the human femoral head we have never been able to obtain the same clear vascular picture that was found in this Centre in studying the vascular characteristics of the upper tibial plate in the rabbit, but basically a similar arrangement prevails.

We have already referred to the part that the terminal arrangement of the vessels penetrating the endochondral head seems to play in the process of ossification; however, considering the importance of the subject a more detailed description will be given elsewhere. It must be emphasised here that for many months after the appearance of the secondary centre of ossification the plate is not directly connected with the epiphysial bone, for it is covered on

FIG. 38

FIG. 39

Female, four years. Microradiograph of a decalcified anterior half (Fig. 38) and posterior half (Fig. 39), showing the large vessels coming from the ligamentum teres but still not connected with the epiphysial vessels. Only one or two small vessels are seen crossing over the surface of the epiphysial plate.

its epiphysial side by many layers of small cells remaining from the old enchondral head; this cartilage has no vessels. Thus the vascular arrangement providing the transudates required for the nourishment of the serial or reproductive cells of the growth plate—that is, the cells nearer to the epiphysis—is situated at a distance which is progressively reduced as time goes on until the bone, and thus the vessels, become close to the plate at about four years of age.

In spite of this migration of the vessels towards the epiphysial side of the cartilage there is no appreciable change in their shape from the time the bony epiphysis is organised until late adolescence. The vessels are large, tortuous and not very close together. They expand

FIG. 40

Male, five years and ten months. Radiograph. The artery from the ligamentum teres is seen penetrating deeply into the epiphysis.

towards the plate and at an equidistant point they either run parallel to the plate for a short way or turn back towards the epiphysis (Fig. 59).

It has not been possible for us to differentiate arteries from veins in this area because all the vessels have similar characteristics, resembling veins more than arteries. No small branches are seen to spring from the main vascular trunks.

On the metaphysial side of the plate the vascular pattern is totally different. The last ramifications of the nutrient artery and the perforating vessels of the femoral neck, together with those coming from the arteries we have elsewhere named upper and lower metaphysial, end in a brush-like pattern (Fig. 60) intimately connected to the distal or hypertrophic layer

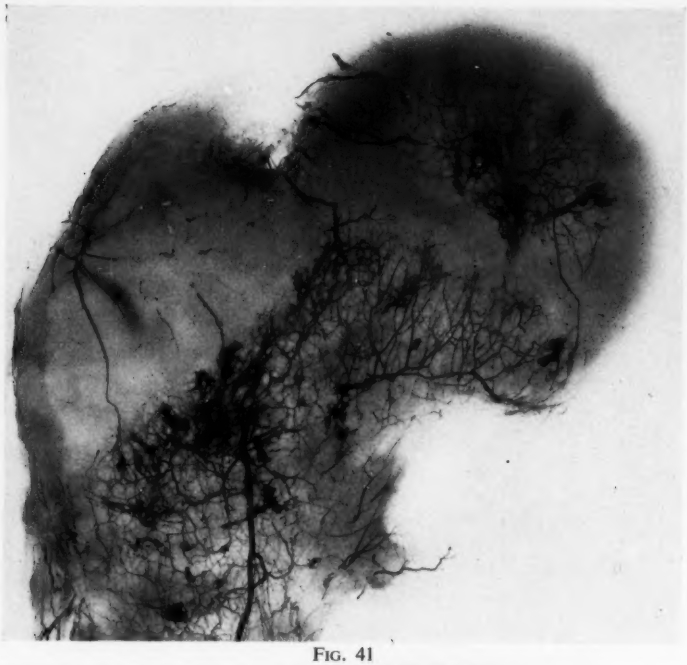

FIG. 41

FIG. 42

Male, five years and ten months. Microradiograph of anterior half (Fig. 41) and posterior half (Fig. 42) after decalcification. The artery from the ligamentum teres is seen anastomosing with the lateral epiphysial vessels and with some small arteries still arising from metaphysis.

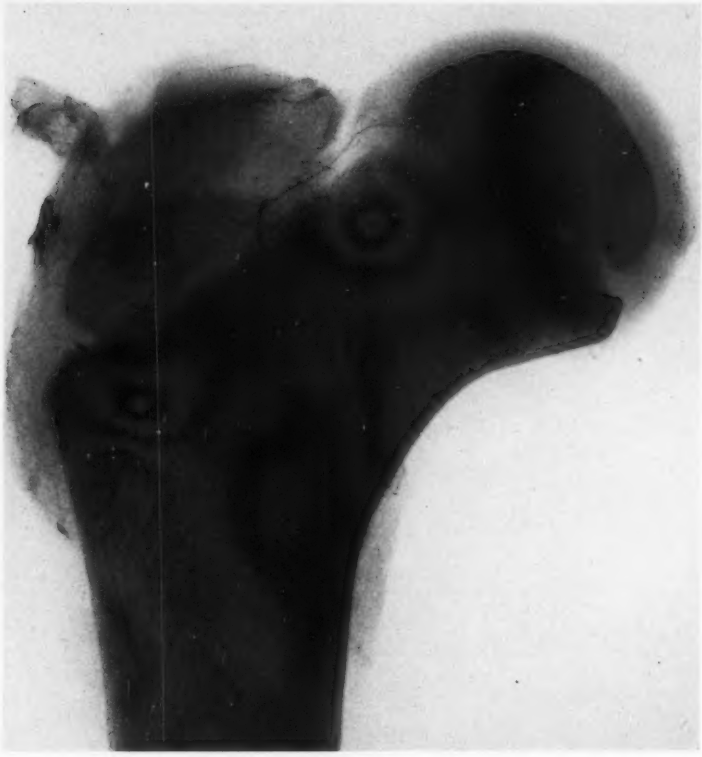

FIG. 43

Male, six years and two months. Radiograph showing the relatively large size of the ossifying trochanter and the length of the neck at this age.

FIG. 44

FIG. 45

Male, six years and two months. Microradiographs of decalcified anterior half (Fig. 44) and posterior half (Fig. 45). The metaphysial vessels practically cease to penetrate the epiphysis. The round ligament still keeps this infantile lack of vascular development.

of cells of the growth plate, each vessel turning back in a sharp loop (Fig. 61). This arrangement is better seen in the tibial epiphysial plate of the rabbit, where each brush seems connected to a single column (or at most two or three columns) of the hypertrophic cells. This intimacy suggests the decisive role that these vessels play in the process of enchondral ossification as will be described elsewhere.

While the growth of the epiphysis is made by apposition of new layers of bone, the mechanism by which this occurs is not yet well understood, particularly in so far as the vessels are concerned. Several observations we have made seem to indicate that, as with the early penetration of the enchondral head by the vessels before ossification begins, new vascular sprouts also precede the laying down of bone (Fig. 62), thus once more linking bone formation with vascular activity.

FIG. 46

Male, nine years and ten months. Microradiograph of a decalcified specimen showing the complete independence of the epiphysial vessels from those of the metaphysis of the femoral head.

DISCUSSION

In the preceding pages I have attempted to give a concise picture of the modifications of the vasculature of the human femoral head from birth to maturation. The general trend that I have observed shows that, with ample room for individual variation, there are five main phases: 1) at birth; 2) infantile; 3) intermediate; 4) pre-adolescent; and 5) adolescent.

Phase 1: at birth—Vessels coming from the lateral side of the head proceed horizontally towards its medial side while other vessels emerge almost vertically from the top of the ossified shaft. Vessels are seen coming from the round ligament, but they are not constant.

Phase 2: infantile—From four months to four years. The predominant blood flow arises from the metaphysial vessels crossing the area later to be occupied by the growth plate; the

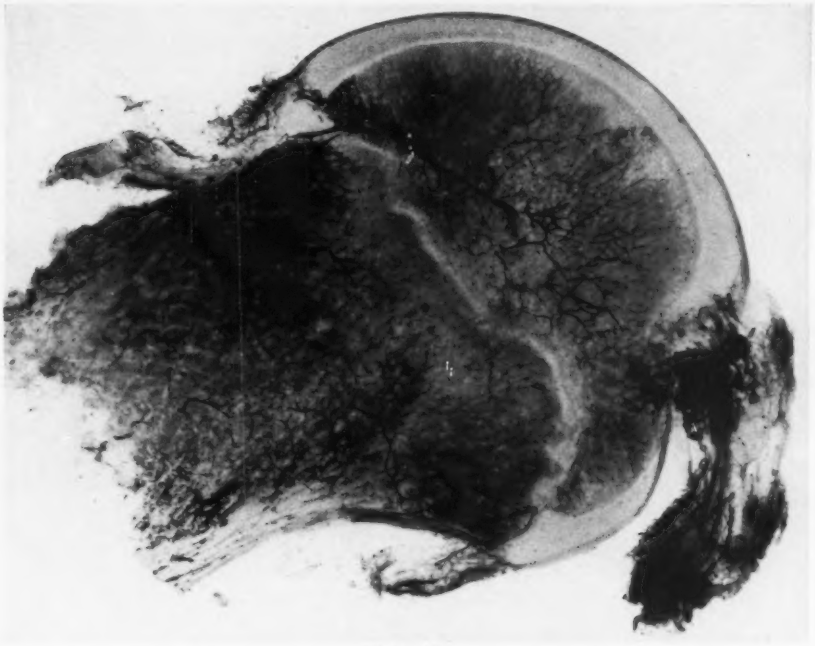

FIG. 47

FIG. 48

Male, eleven years. Photographs of Spalteholz preparation of anterior half (Fig. 47) and posterior half (Fig. 48), showing that not a single vessel crosses over from the epiphysis to the metaphysis while (Fig. 48) a rich vascular anastomosis of the adult type already exists between the arteries of the ligamentum teres and terminal vessels from the lateral epiphysial arteries.

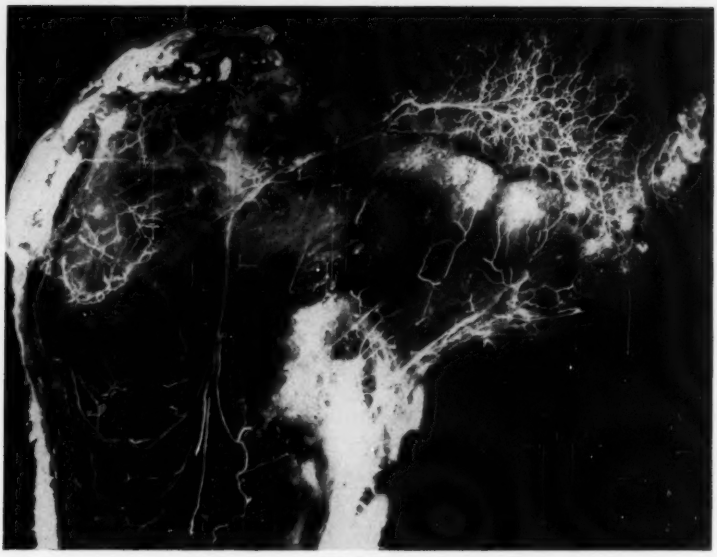

FIG. 49

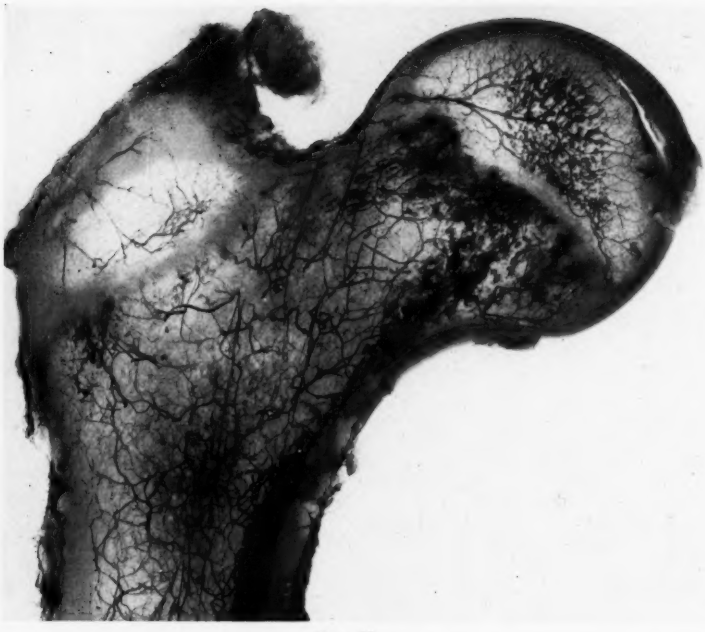

FIG. 50

Female, thirteen years. Photograph of Spalteholz preparation showing the whole femoral head, and (Fig. 50) microradiograph showing the complete independence of the epiphysis from the metaphysial blood supply as the vessels of the ligamentum teres penetrate the femoral head.

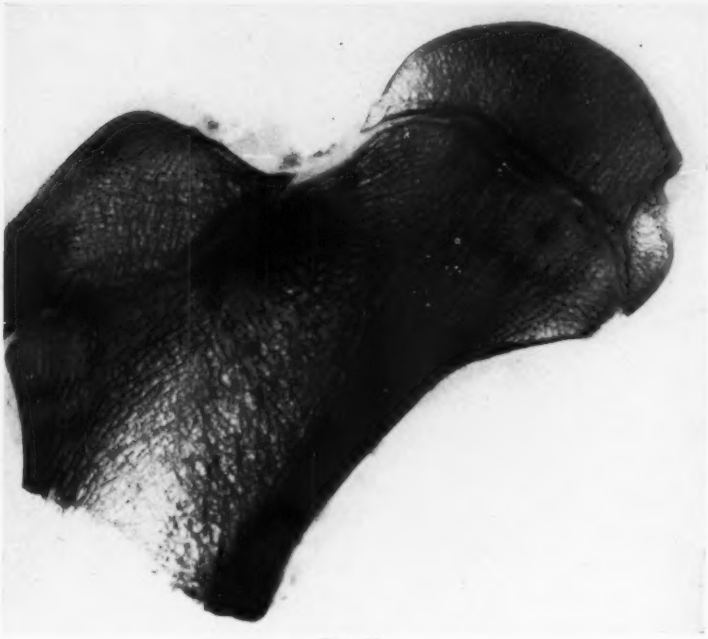

FIG. 51

FIG. 52

Female, fourteen years and three months. Radiograph showing complete maturity of the trochanter epiphysis, and (Fig. 52) photograph of a section of the upper femoral epiphysis showing the persistence of the single growth cartilage under the femoral capital epiphysis and the trochanteric epiphysis.

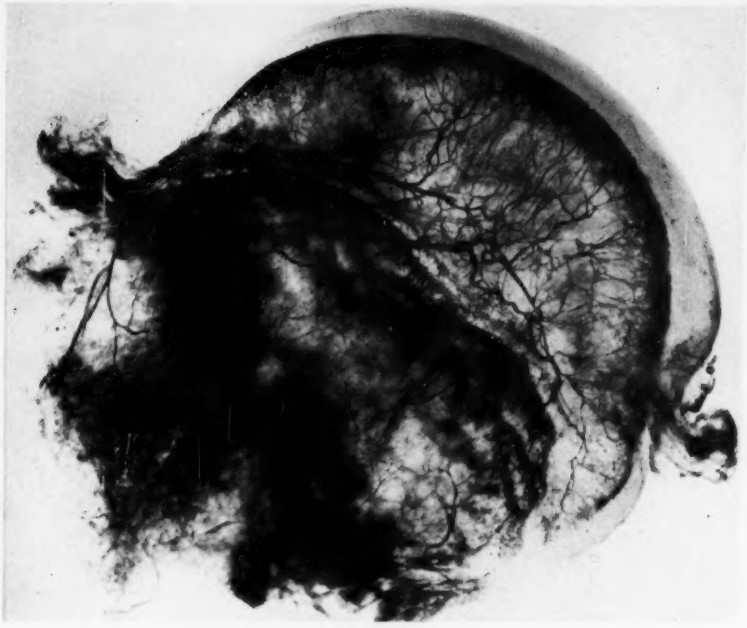

FIG. 53

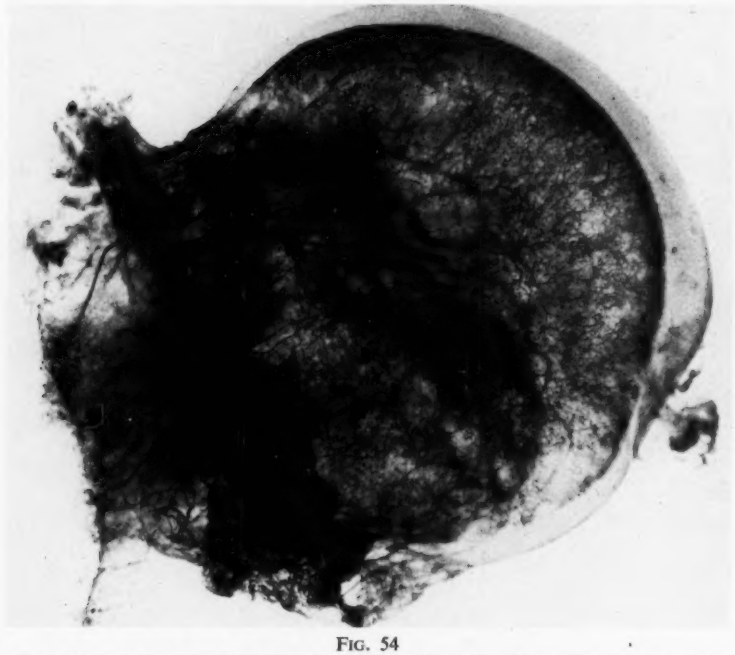

FIG. 54

Female, fourteen years and three months. Photographs of Spalteholz transparency showing (Fig. 53) excellent injection of the end vessels under the metaphysial side of the plate, and (Fig. 54) lateral epiphysial vessels at the moment of branching off the medial circumflex artery.

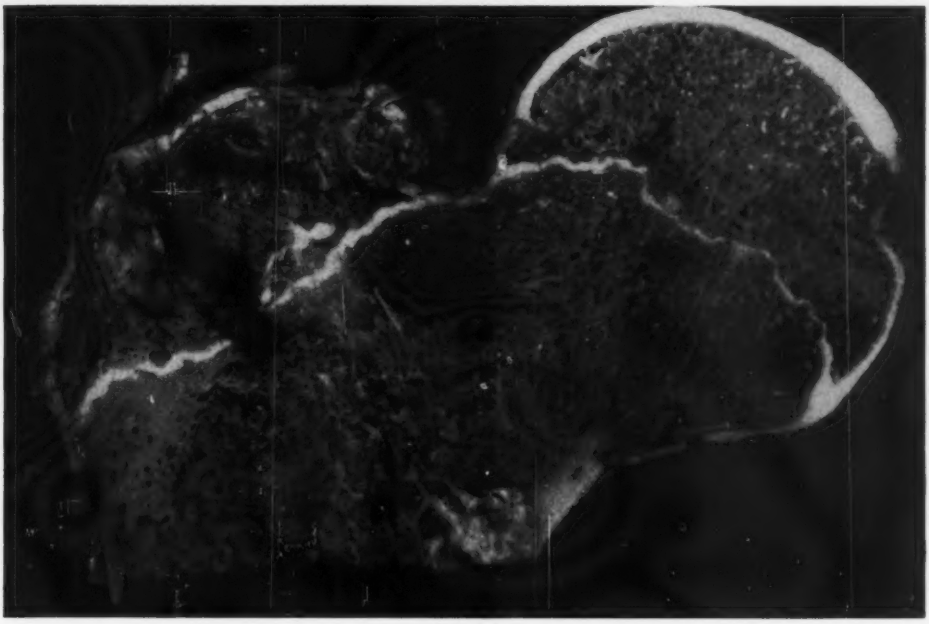

FIG. 55

FIG. 56

Male, fifteen years. Figure 55—Photograph of a section of the femoral head showing reduction in height of the epiphysial plate, which precedes final closure of the growth cartilage. Figure 56—Microradiograph after decalcification. An excellent vascular supply from the ligamentum teres is seen.

FIG. 57

FIG. 58

Female, seventeen years. Figure 57—Radiograph showing complete fusion of both upper femoral epiphyses. Figure 58—Photograph of Spalteholz preparation of the same specimen, in which the adult type of circulation has been finally achieved.

lateral epiphysial vessels are also important, but there are no penetrating vessels coming from the ligamentum teres even if in the early days some large vessels are seen to enter the head from this source. They soon disappear.

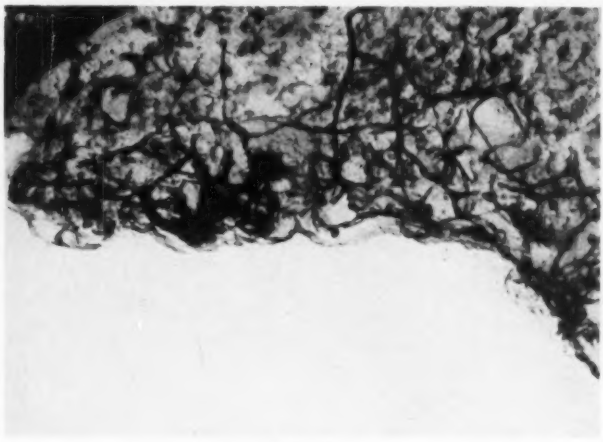

FIG. 59
The tortuous vessels of the epiphysial side of the growth plate. (×40.)

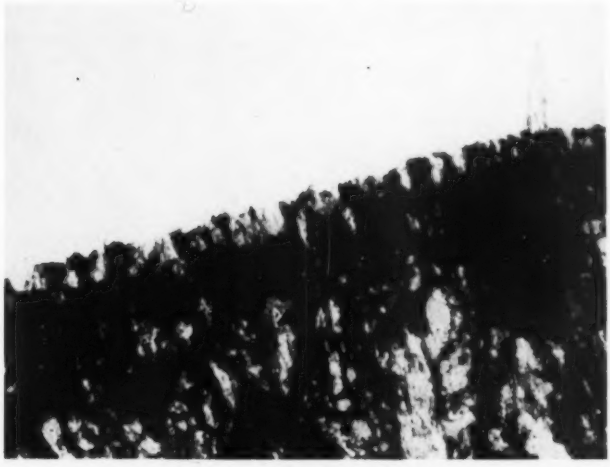

FIG. 60
Brush-like pattern of the vessels at the metaphysial side of the growth plate. (×40.)

Phase 3: intermediate—From about four to seven years. The epiphysial plate has established a firm barrier between epiphysis and metaphysis. The metaphysial blood flow decreases to become negligible, or nearly so, while the round ligament has not yet provided vessels penetrating the epiphysis. During these two or three years the only source of blood to the epiphysis comes from the lateral epiphysial vessels, all of them tightly grouped on the lateral aspect of the head.

Phase 4: pre-adolescent—Nine or ten years. Here, while the growth plate acts as a closed barrier to the vessels, the arteries from the ligamentum teres finally reach the depths of the epiphysis and become anastomosed to other vessels, all of which are branches of the lateral

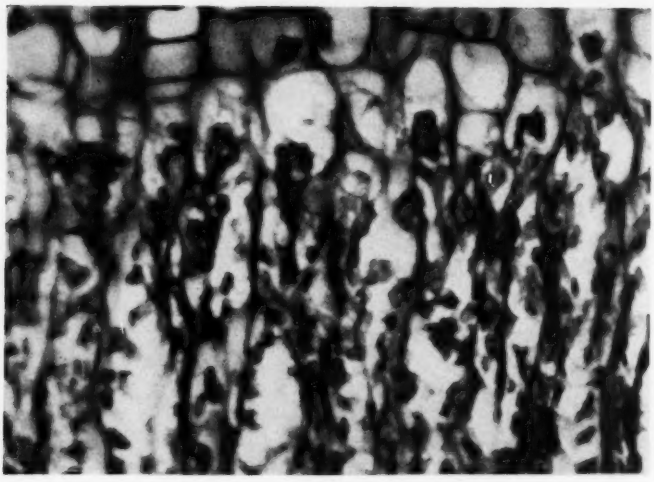

FIG. 61
Sharp vascular loops over the hypertrophic cells of the growth cartilage. (×300.)

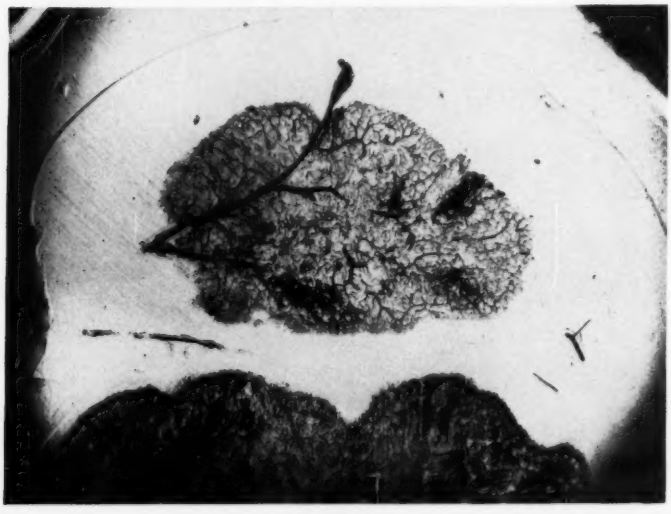

FIG. 62
Vascular sprout preceding the laying down of new epiphysial bone. (×4.)

epiphysial arteries. Thus at this stage the epiphysis receives blood from two main sources situated at the greatest possible distance from each other.

Phase 5: adolescence—Here the barrier of the epiphysial plate begins to break down and vascular anastomosis crosses over, bringing into being the final or adult stage of the circulation

where the epiphysial and round ligament vessels are joined again to those of the metaphysis, giving to the femoral head the vascular interwoven pattern previously described (Trueta and Harrison 1953).

It is beyond the scope of this paper to speculate on the possible implications of the peculiar modifications of the vasculature of the growing human femoral head, but mention may be made here of some of the disorders that the above findings might help to explain.

From one to three years of age—The delay in appearance and retarded development of the secondary centre of ossification of the femoral head in congenital dislocation of the hip and its increase in size after proper reduction (the lateral epiphysial vessels are occluded by the capsular pull, but the metaphysial are still open to the circulation).

From four to seven years of age—Legg-Perthes' disease. Normal absence of blood supply from the ligamentum teres and poor or none from the metaphysial vessels; the only real source, the lateral epiphysial vessels, may become obstructed by trauma or inflammation.

From eleven to fifteen years of age—Slipped epiphysis. This is a period of great vascular activity in the metaphysial side of the growth plate preceding the fusion of the epiphysis.

It is proposed to submit in the near future a more detailed study of the possible implications of this work to interpret the nature of juvenile osteochondritis of the Legg-Perthes' type.

SUMMARY

1. The results of a study of the characteristics of the vessels found in forty-six human femoral heads during the growth period are described.

2. Of the three different sources of blood entering the human adult femoral head it was found that from birth to about three to four years the vessels of the ligamentum teres do not contribute to the nourishment of the head.

3. After the fourth year the metaphysial vessels decrease in importance until they finally disappear, leaving the head with only one source of blood through the lateral epiphysial vessels; the ligamentum teres is not yet contributing to the circulation of the head.

4. After about eight or nine years it was found that the vessels of the ligamentum teres contribute to the blood supply of the head while the metaphysial blood flow is still arrested.

5. Finally, at puberty, after a period of activity of the metaphysial vessels, epiphysial fusion takes place, bringing together the three sources of blood characteristic of the adult.

This work would have been impossible without the help received from a number of workers who assisted me in injecting and preparing the specimens, among them M. H. M. Harrison, R. Esteve, C. Lima, A. Trias W. Waugh and L. H. Pimm. I also wish to thank Dr A. H. T. Robb-Smith for the facilities provided in the necropsy room of the Department of Pathology, Radcliffe Infirmary, Oxford, and to Dr G. M. Ardran for his assistance in microradiography. My thanks are also due to Mr A. H. Mann and Miss A. Bird for their help in our Laboratory and Photographic Department respectively.

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STUDIES OF THE VASCULARISATION OF BONE GRAFTS

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The purpose of the present work was to obtain data on the vascularisation of bone grafts, with particular reference to the vascular pattern and rate of vascular penetration into the implants. Autogenous, homogenous and heterogenous bone was studied simultaneously to allow these two factors to be compared in the three types of graft.

REVIEW OF LITERATURE

A copious literature, including many accounts of experimental studies on bone grafting and on the different behaviour of autogenous, homogenous and heterogenous implants is already available. Among these contributions only a few are dedicated to describing the vascular pattern of the bed and graft and most of these give only scanty or unsupported evidence of the vascular behaviour in bone grafting.

Marchand (1901) seems to have been the first to study the vessels in transplanted bone; only a few isolated sections of each graft were studied in dogs, and no photographic records were obtained.

Läwen (1909) described the vessels in a human tibial graft after excision of a sarcoma of the humerus, and showed a drawing of the specimen.

Nemilow investigated the part played by the periosteum in the early vascular penetration of the graft; so far as we know from the quotation of Petrow (1914), the most important result of his eight experiments in rabbits was to show that in the first six days the transplanted periosteum was vascularised, whereas no vessels were to be seen in the bone without periosteum. Bertini (1926) used only autogenous bone to study the behaviour of the vessels near and in the holes he had made in the bone of rabbits. Unfortunately only four photomicrographs with very little magnification were given in his paper. Rubaschewa and Priwes (1932) studied the macroscopic modifications of the vascular network around the graft in dogs of various ages, particularly in the periosteum; no account was given of any fine vessels or of the microscopic characteristics of the graft. May (1937) observed the macroscopic modifications of the vessels in a radius experimentally transplanted, without giving any details of the vessels.

The two main contributions based on recorded experimental data will now be considered. Hancox (1947) observed directly the vascularisation of small grafts transplanted to the chorio-allantoic membrane of the chicken; the size and the type of the fragments (frontal bone) and of the bed used seem too far removed from clinical practice in orthopaedic surgery to allow any definite conclusion to be drawn from this work. Kiehn *et al* (1952) followed the evolution of the vascular pattern in grafts transplanted in transparent chambers; here also, as the authors pointed out, the bed and the size of the fragments were quite unusual and this may explain the different rate of vascular penetration compared with that which we have found.

Apart from these few papers, some hundreds of the two thousand odd works relating to bone grafts mention the vessels; yet only from a few of them is it possible to gain any information on the vascular pattern and the rate of penetration. Trying to assess from these investigations the rate of penetration of the vessels in autogenous grafts we find the following.

Hancox (1947) saw functioning vessels in a graft after only five hours from its implantation; Nemilow (quoted by Petrow 1914) found the injected substance in the vessels of periosteum transplanted two days previously, and Gallie and Robertson (1919) after the

same time saw new capillaries in the opened Haversian canals. Bertini (1926) and Urist (1953) could only observe the earliest signs of revascularisation at the fifth day. Kiehn *et al.* (1952), working with very small fragments, could not find vessels inside the graft before the eleventh day but found almost complete vascular penetration after two weeks. Marchand (1901) also saw many injected vessels in the grafts of the skull after two weeks.

Kreuz *et al.* (1951) saw evidence of vascularisation of the homogenous graft after thirty-five days, and the greatest penetration after sixty to ninety days. Siffert (1955) could not see any vascular invasion after six weeks. Wilson (1951) reported good vascular penetration in twelve weeks.

The great variation between these results seems to be due to such causes as the different type and size of the transplant and bed, the technique followed in grafting, and particularly the method employed to show the vessels. With the available material it is impossible to acquire a documented view of the process of revascularisation in the three different types of graft commonly used in bone surgery. Furthermore, there has been no accurate three-dimensional visual representation of the vascular pattern of the graft and the bed, because this cannot be seen in simple histological preparations; it may however be obtained from a technique which combines microradiography and microphotography of transparent specimens.

METHODS

Young rabbits and guinea pigs towards the end of the growth period were used. The rabbits were not only of the same race but for several years they had been inbred, and this must be borne in mind in the interpretation of the results of the homogenous grafts. Both cortical and cancellous bone was transplanted. It was obtained from the distal shaft and metaphysis of rabbits and guinea pigs. The grafts were placed in the lower femoral metaphysis and on the surface of the kidney, under the renal capsule. The technique was as follows. Under general anaesthesia with nembutal-ether the lowest third of the rabbit's femur was exposed through a medial incision. The periosteum was detached from the bone, care being taken not to disturb its connection with the surrounding tissue. A rectangular fragment 2·5 centimetres long and 0·75 centimetre wide was cut with an electric saw from the anterior femoral surface, just below the inferior epiphysial plate and reaching proximally to the cortical bone of the shaft; the marrow space was thus opened. A chisel was used instead of the saw in a small number of experiments. Part of the bone obtained was put in the bone bank refrigerator for use as a homogenous graft in another rabbit. After waiting some minutes in order to stop any bleeding, a fragment 1 centimetre by 0·5 centimetre was turned 180 degrees through its length and was reimplanted in the same place, the upper part now being the lower, but deep into the marrow cavity. Adjacent to it two other fragments of the same size, of homogenous and heterogenous bone, which had been kept in the refrigerator for a time varying from five to sixty days, were also implanted. Some fragments included articular cartilage, and some the thin cortex of the metaphysis, and some, from young animals, contained part of the epiphysial plate. The position of these structures was recorded exactly, because the main purpose of the work was to study the rate of vascular penetration into the three types of bone implants, and the position of the graft in the bed may influence vascular penetration. In other cases fragments of cortical bone, 0·5 centimetre by 0·5–1 centimetre, were used instead of the metaphysial cancellous bone. The skin was sutured with silk; no plaster immobilisation was used. Next, a laparotomy was performed through the linea alba; the capsule of the kidney was incised; an autogenous bone fragment, like that already grafted in the femur, and refrigerated homogenous and heterogenous bone fragments, were lodged between the capsule and the parenchyma. The use of an electric saw, and of fresh autogenous grafts and of refrigerated homogenous and heterogenous grafts, was made in order that the technique should conform to the procedures prevailing in man.

The animals were killed at times varying from two to ninety days after the grafting.

For the study of the blood vessels, techniques used in previous investigations in this Centre were employed (Trueta, Barclay, Daniel, Franklin and Pritchard 1947 Trueta; and Harrison 1953). Under general anaesthesia the chest was opened, a needle was introduced into the thoracic aorta, and about 100 cubic centimetres of 2 per cent Berlin Blue solution was injected; in cases for radiological analysis barium sulphate suspension (Micropaque) was mixed with Berlin Blue in a proportion of 1:1. Femora and kidneys were removed after varying periods, freed from the surrounding tissue, fixed in 10 per cent formalin and radiographed. They were then decalcified and made transparent by the Spalteholz technique so that the injected vessels could be studied in detail.

After the preliminary examination each specimen was repeatedly sectioned in various planes, and studied under the dissecting microscope. Photographs were taken of most sections. Microradiographs by the technique described by Barclay (1951) were also obtained of the specimens that had been injected with the radio-opaque medium. Other specimens were prepared for histological study.

Altogether 119 bone grafts were studied; thirty-eight were autogenous, thirty-nine homogenous and forty-two heterogenous. Fifty had been implanted into the femur and sixty-nine under the renal capsule. The autogenous grafts were all fresh; the homogenous and heterogenous grafts were preserved by refrigeration.

RESULTS

AUTOGENOUS GRAFTS

Marked differences in the vascular behaviour were found between cortical and cancellous grafts, and according to whether the bed used was femoral or renal.

Cancellous bone—The fragments implanted in the femur were mostly placed with the articular cartilage superficial in order to give the best conditions for a quick penetration through the intertrabecular spaces opened towards the bed.

At the end of the first week the specimens of grafts placed in the femur were found to be already adherent to the deep structures of the medullary cavity; only slight elastic displacement was possible and in the numerous sections made with razor blades the autogenous fragment never became detached from its bed, giving evidence of an already well established organic connection. This was not always found with the same type of fragments placed under the renal capsule, even if the latter appeared very well vascularised with newly formed vessels. The Spalteholz technique is particularly suited for this study because the limits of the graft are easily seen owing to differences of light refraction.

Two types of vascular pattern were found penetrating the graft from the bed. In one, single vessels or groups of vessels were seen passing from the bed to the graft (Fig. 1); the normal circulation, as existing in the bed, extended into the transplanted bone almost without modification. It was, for instance, possible to follow for a long distance a relatively large vessel, coming from the surrounding bone and crossing over the border to enter deeply into the graft. Sometimes three or four narrow vessels of the bed would join together close to the border to form a larger vessel which then ran into the graft. The other type of pattern appeared as a thick network formed by many small branches anastomosing with each other, and extending as a vascular belt directly over the graft (Fig. 2). This network was derived from large vessels dividing into numerous diverging branches; in the kidney these vessels often came from the thin subcapsular network superficial to the glomeruli. The network adhered to the graft and followed its boundaries but did not penetrate it. Single vessels emerged from the junction of many others and penetrated into the graft only in a few isolated points; perhaps no more than one for an area of a square millimetre.

These two different patterns were explained by the structure and position of the transplant. If the medullary side of the graft was directly facing the vascular network of the bed, and its

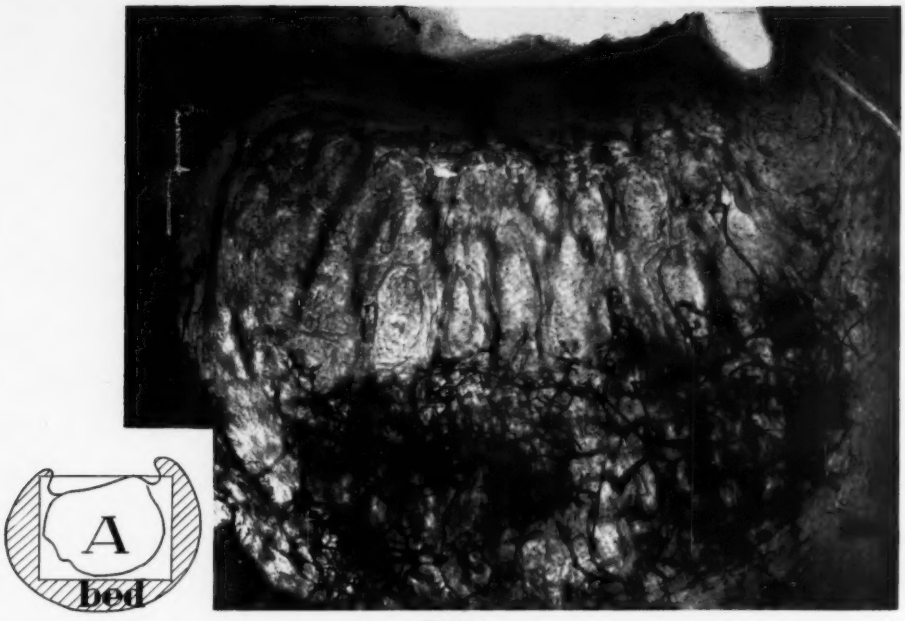

FIG. 1

Autogenous cancellous graft seven days after transplant on to a femur. (×18.) The graft is already vascularised for half its thickness (2½–3 millimetres).

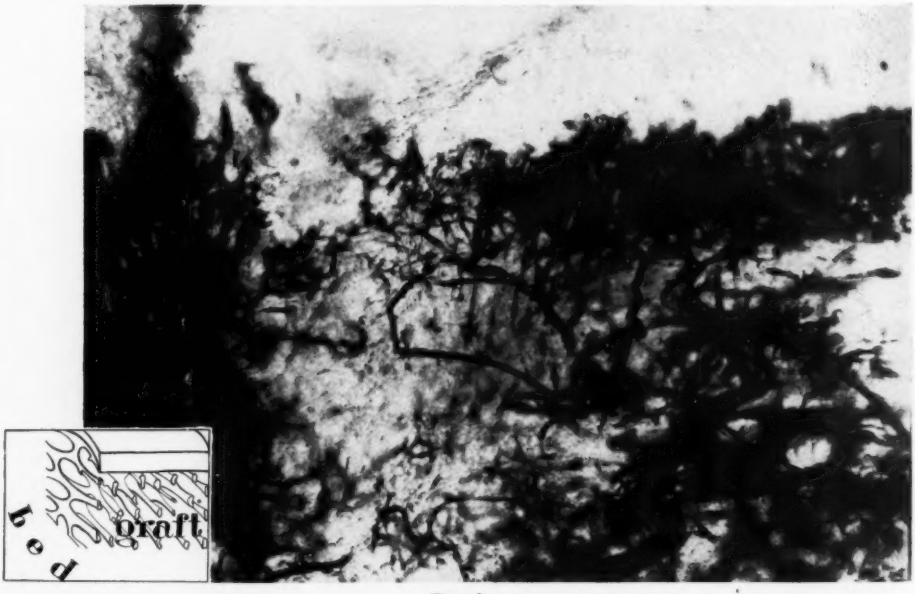

FIG. 2

Autogenous cancellous graft six days after transplant on to femur. (×35.) There is a network of vessels lining the cortical surface of the graft. In the lower part of the photomicrograph the open intertrabecular spaces are already well penetrated.

trabeculae were perpendicular to the surface of the bed, the vessels penetrated it easily. If, however, the trabeculae of the graft were placed parallel to the surface of the bed, and were rather large and strong, or if, moreover, some other obstacle existed such as a thin metaphysial or epiphysial cortex, or articular cartilage, a network was first formed superficial to the graft and initially only isolated vessels were able to penetrate the graft, through pre-existing channels or after osteoclasis.

The course of the penetrating vessels of either pattern was sinuous, the vessels clearly

FIG. 3

Autogenous cancellous graft seven days after transplant on to femur. (×40.) The diagram shows the two trabeculae placed across the line of penetration. The photomicrograph shows the capillary network lining the two trabeculae: one vessel from the inferior network has succeeded in piercing one trabecula and branches out again.

adapting themselves to the shape of the trabeculae. They advanced through the medullary spaces within the trabecular frame and turned around them when they became an obstacle to their progress. It was noted in many cases that the vessels were adherent to the trabeculae, and advanced in close contact with them (Fig. 3). When a graft 0·5–0·6 centimetre thick had been placed in the best conditions to favour vascular penetration it was found already vascularised for half of its thickness after only seven days. A fragment 0·3 centimetre wide placed on the kidney was found completely penetrated by many vessels after six days (Fig. 4).

At this initial stage the vessels were often fairly big in calibre and ended rather abruptly, after two or three divisions, still keeping their large size; small capillaries branched from them but soon ceased. It is possible that for some reason the whole of some capillaries could not be perfused by the injection mass, perhaps from lack of sufficient pressure of the injected fluid; but it seems more likely that the penetrating vessels become wider towards their termination because of the peculiar attraction that the invaded tissue exercises on the vessels of the bed. This phenomenon is being studied in this laboratory at present.

The pattern of an isolated, rather thick vessel with few collateral branches and an abrupt ending was commonly found situated deeply in the graft. A rich network, perhaps arranged as a candelabrum, with many big branches diverging from a single stem, seemed to appear when there was marked resistance to the vascular penetration.

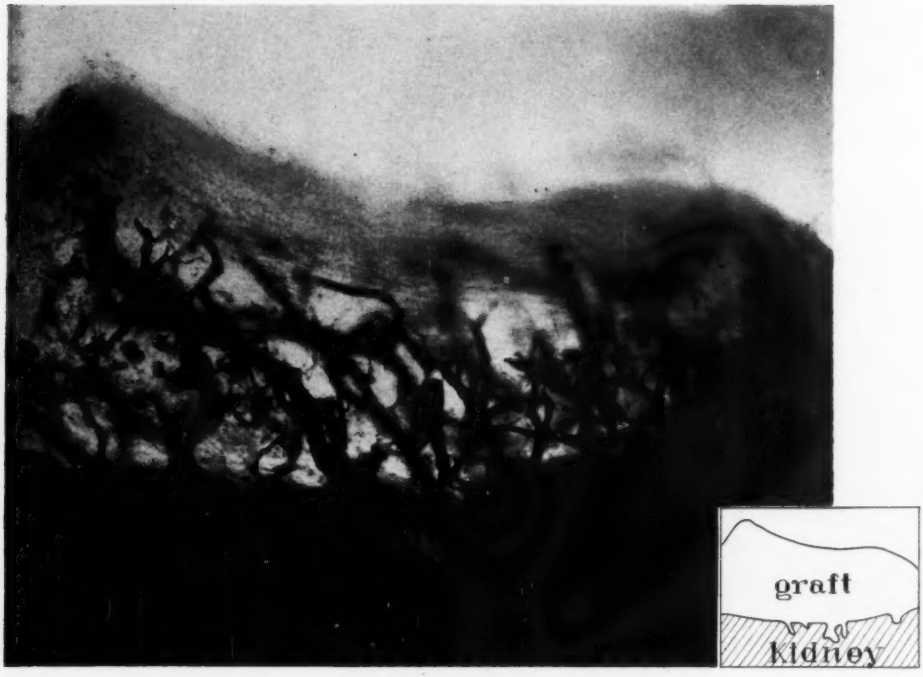

FIG. 4

Autogenous cancellous graft six days after transplant on to kidney. (×80.) The vascularisation is conspicuous. The renal parenchyma whence the vessels come is seen black below.

During the second week the vascularisation gradually progressed. The border of the transplanted bone in the femur could still be outlined but it was now losing its sharpness.

At this stage the usual pattern in the femoral specimens was of numerous, even if not very crowded, vessels, forming a band just across each border of the graft. In this area the vascular arrangement no longer followed the structure of the transplanted bone; as could be seen in the histological sections the vascular band corresponded to the layer of hyperaemic granulation tissue which was already far advanced in removing the dead trabeculae and in laying down new bone. There were gaps in the vascular penetration in some isolated places; these corresponded to the presence of a barrier to the progress of the vessels from the bed, and it was here that the thick capillary network, which has already been described, was to be found.

Inside the graft the vessels continued their penetration. They seldom formed definite groups because they were quite widely spread throughout the graft; isolated vessels could be seen very deeply, having left other vessels and the granulation tissue far behind. Whether this feature may be considered indicative of a recanalisation of the old vascular system or not will be discussed later.

In the kidney the pattern was not so uniform. Some fragments showed a marked vascular penetration for a few millimetres, even although not always as rich in vessels as in the femur (Fig. 5). In certain other fragments only a single, not very deep, vascular tuft was found and in others only a few isolated capillaries crossing the bone for about two millimetres

FIG. 5

Autogenous cancellous graft ten days after transplant on to kidney. (×100.) The black, lower part of the photomicrograph represents the subcapsular network of the kidney, with the superficial glomeruli, from whose capillaries the vessels which penetrate the graft directly originate.

were noted. These variations may be explained by the different characteristics of the blood supply of the renal capsule as compared with that of the lower end of the femur, particularly with reference to the distribution of the vessels. Commonly the main vessels of the subcapsular area of the kidney are situated somewhat apart from each other.

At the end of the third week the autogenous grafts in the femur were found vascularised for five-sixths of their depth (Fig. 6); only the areas more remote from the bed usually were not reached. Some vessels inside the graft, surely newly formed, were about eight millimetres long. The general arrangement was as follows: it was no longer possible to recognise the borders of the graft, but some increase of the vascular network still persisted in that area. The centre of the graft was penetrated in many directions by vessels of different sizes and

FIG. 6

Autogenous and homogenous cancellous grafts twenty-four days after transplant on to femur. (×10.) Four-fifths of the autogenous bone has been invaded by new vessels. The area at the summit is not reached by the vessels because a portion of the epiphysial plate had detained the vessels coming from the right. The smaller homogenous fragment has in this case a fairly good vascularisation. *Top*—Injected specimen. *Bottom*—Histological section.

irregular disposition. But again, in the more distant parts of the graft, the advancing vessels followed paths which are indicated by the architecture of the graft.

Histological examination at this stage showed young mesenchymal tissue invading the dead trabeculae in the regions nearest to the bed, with extensive osteoclastic reaction and appositional bone growth here and there. A new tissue was being laid down but the dead trabeculae far from the bed were still unaltered and were reached only by a few vessels.

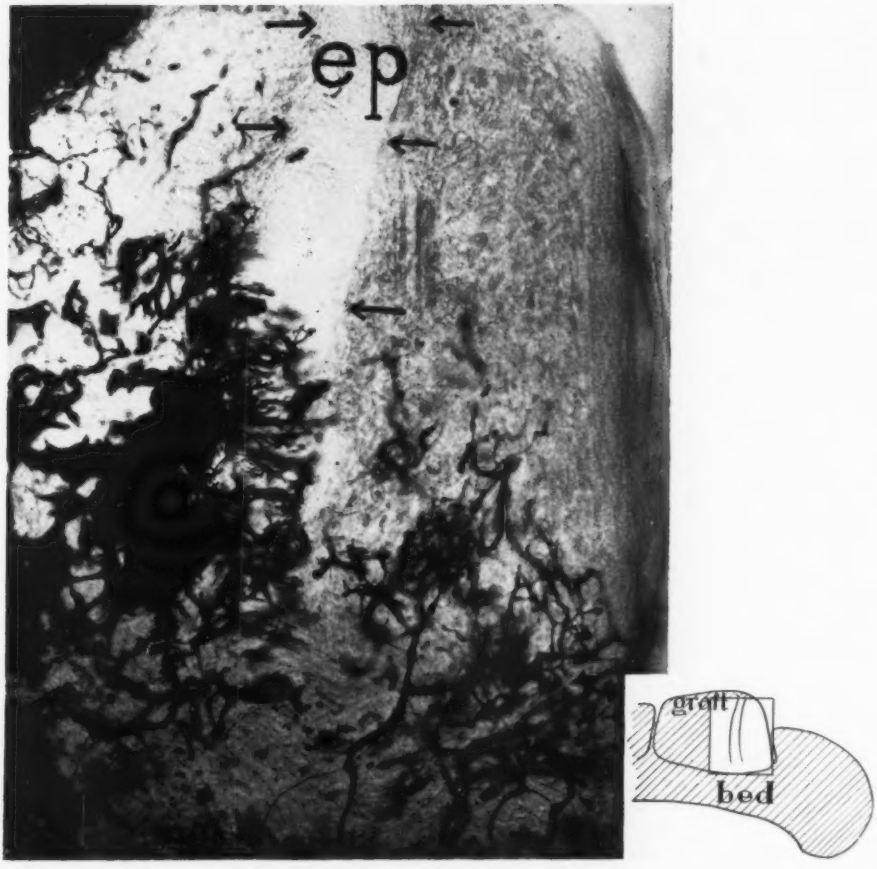

FIG. 7

Autogenous cancellous graft twenty-one days after transplant on to femur. (×40.) An extensive network with a sinusoid system is lining the epiphysial plate of the transplant which is situated across the line of penetration of the main vessels. Capillaries are slowly advancing from it by a chondroclastic process. Running up from the lower right-hand corner other vessels are advancing unimpaired.

An interesting relationship was noted between the vessels and the transplanted cartilage of the articular surface and the epiphysial plate. Cartilage represented an insurmountable obstruction for a long time when it lay across the line of penetration of the vessels (Figs. 6 and 7), and it was only after thirty days that evidence of its perforation by isolated vessels was found (Fig. 8). Next to them was the usual pattern of a delicate network from which a penetrating branch was seen at only two or three points. In contact with the articular cartilage sinusoids were to be seen forming broad juxtamedullary capillary loops which have been

FIG. 8

Autogenous cancellous graft on to kidney after thirty days. (×40.) Penetration of vessels through transplanted articular cartilage covering the bone graft. The vascular network of the renal capsule has been removed; in only three places a small number of vessels were able to reach the underlying cancellous bone.

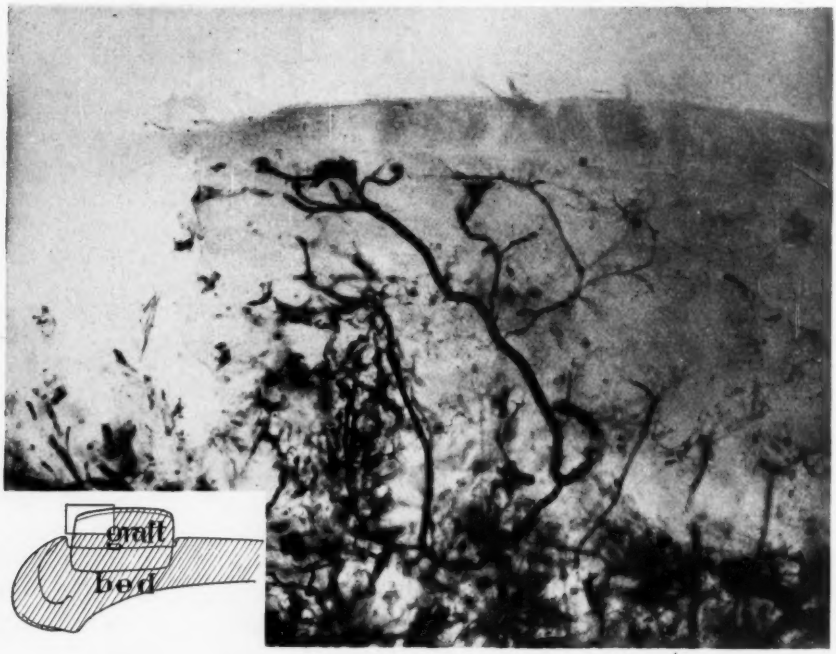

FIG. 9

Autogenous cancellous graft thirty-five days after transplant on to femur. (×35.) Subchondral sinusoids and capillary loops are seen at the end of a large vessel. The darker, narrow layer in the upper part of the photomicrograph is the articular cartilage of the transplanted fragment.

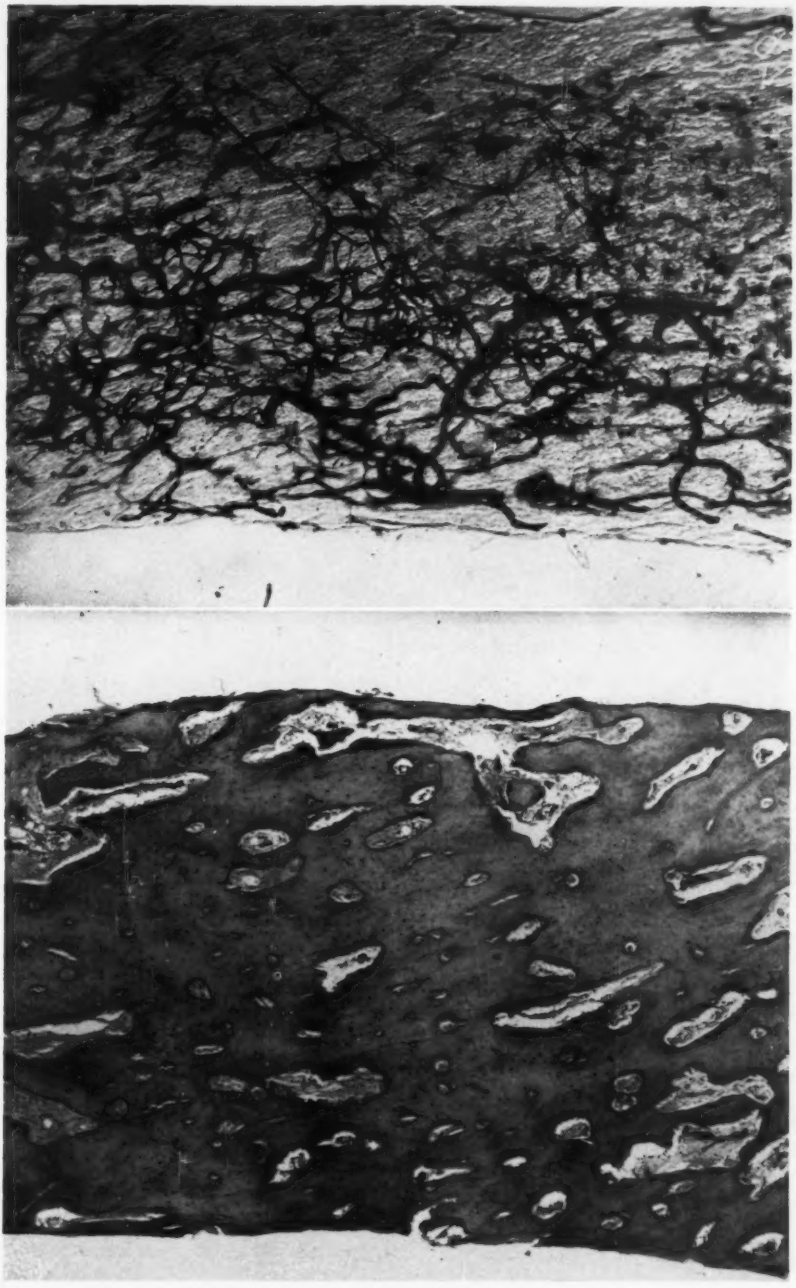

FIG. 10

Autogenous cortical graft twenty-one days after transplant on to kidney. (×45.) At the lower part of the microradiograph (*top*) vessels coming from the subcapsular renal network have penetrated deeply on to the graft. The histological section (*bottom*) shows the dilated Haversian canals with newly formed vessels and young connective tissue. Osteoclasis and bone apposition are occurring at the same time.

described in normal bone by previous investigators (Trueta and Harrison 1953) (Fig. 9). We will return again to the interpretation of these findings.

A venous system inside the graft was now clearly recognisable; it drained into the large veins of the middle of the marrow cavity, with larger vessels often characterised by their elliptical appearance in section.

In the kidney no uniform results were found. In one case only a very superficial vascularisation was obtained; in another a few isolated capillaries through the bone graft were seen; and in a third an almost complete penetration was obtained (Fig. 10).

After one month the autogenous graft in the femur was revascularised throughout (Fig. 20), although certain areas, such as the more distant or those protected by some barrier, were less rich in vessels. The borders of the graft were no longer visible, but they were indicated by an abnormal vascular arrangement. In the depth of the marrow cavity there appeared a pattern of scattered irregular opacities representing the sinusoids of the red marrow, crossed over by a few important arteries and veins. These opacities, resembling those normally observed in the metaphysis near the epiphysial plate, which correspond to venous enlargements, were also noted against the transplanted epiphysial plate within the graft.

The graft on the kidney showed an almost complete vascularisation at this stage (Fig. 21).

After forty days the number of vessels in the graft decreased. In a longitudinal section of the femoral specimen, the trabecular structure of the graft could r.o longer be distinguished from its bed by naked eye, which had been possible two weeks before. The only remaining portion was the articular cartilage and a layer of dense bone beneath it. The femoral metaphysis appeared normal except for the peripheral area.

Histological sections showed remnants of necrotic trabeculae with poor appositional growth, with scattered areas of bone marrow and sparse connective tissue. The cortex was in the midst of marked osteoclastic and osteoblastic changes.

On the kidney the vessels were also fewer in number than ten days before; because of reabsorption the fragment was no more than half its original thickness and the capsule over it was still well vascularised.

After ninety days the fragment transplanted in the kidney showed very few small narrow vessels connected with those of the capsule; the histology demonstrated haemopoietic living marrow, as already observed by Lacroix (1949), in a framework of dead trabeculae which was being reabsorbed.

Cortical bone—*Before the third day* the fragments of cortical bone were still completely avascular. In one of the grafts in the kidney hyperaemia was noted in the capsule and in the subcapsular network of the renal parenchyma outside the glomeruli. The capsule was detached quite easily from the bone. A fine vascular network was to be seen also around the fragment of the femur. The histological sections showed a thin layer of non-organised tissue separated from the bone by the newly formed vascular network.

After seven days the capsule was still more hyperaemic and was more difficult to detach from the graft. Three or four narrow branching vessels, coming from the capsule, ran through the whole thickness of the graft from one surface to the other (Fig. 11). They were newly formed vessels penetrating pre-existing canals; in one specimen this was clearly seen (Fig. 12).

At the end of the third week some of the specimens showed a pattern quite like that of the previous week, the graft being pierced by only a few capillaries. Others, on the contrary, were completely penetrated by numerous vessels, establishing an intricate network with branches and anastomoses (Fig. 13). We were unable to find the reasons for such a difference.

On the fiftieth day the fragment placed in the femur at the same level as the normal cortex was found firmly fixed to the underlying bed. Under the dissecting microscope it appeared perforated by many narrow vessels, mostly from the marrow cavity (Fig. 14). It seemed that some superficial areas were not yet reached. In the kidney the vascularisation was less good; one graft was penetrated by capillaries to half its thickness at only four or five points.

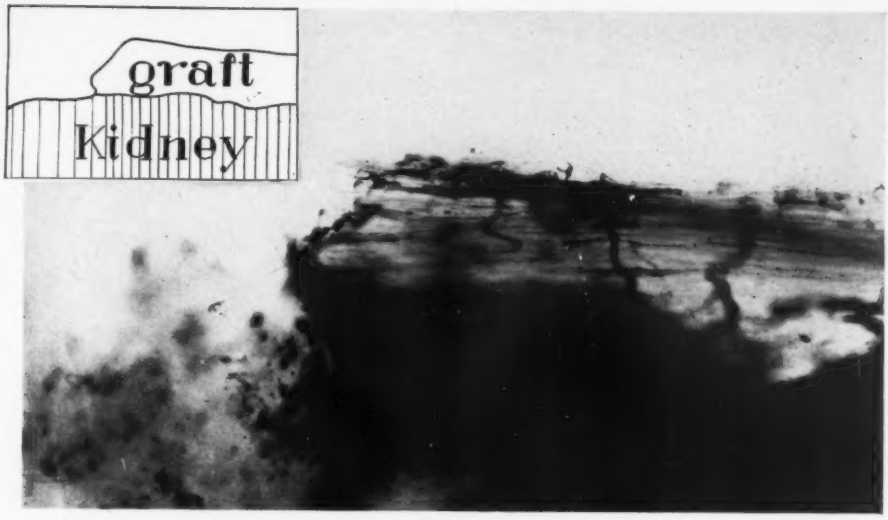

FIG. 11

Autogenous cortical graft eight days after transplant under renal capsule. (×10.) It has been already completely pierced by some vessels coming both from the capsule and from the subcapsular renal network.

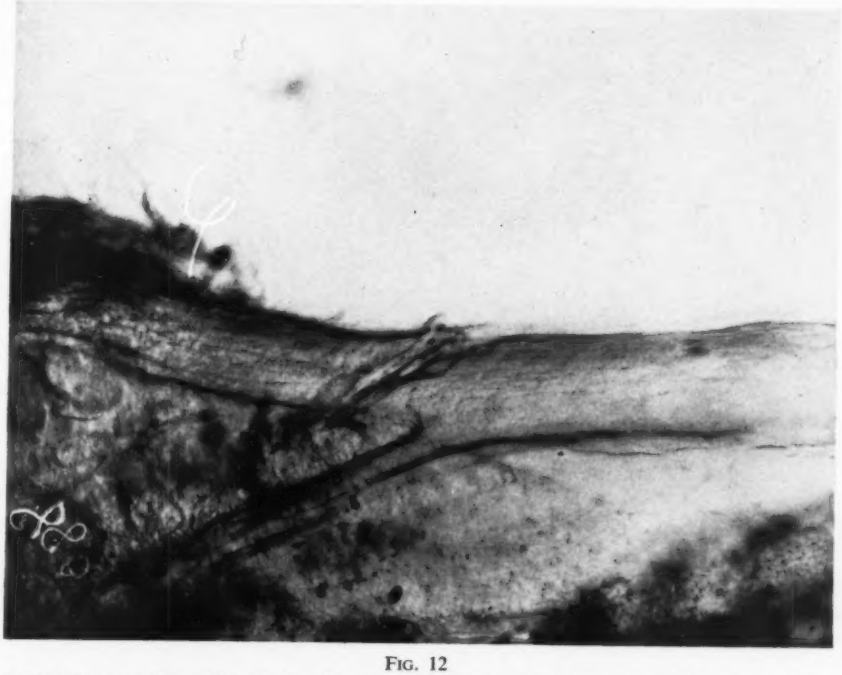

FIG. 12

Autogenous cancellous and cortical graft twenty-five days after transplant under renal capsule. (×45.) A capillary is piercing the cortex through a pre-formed canal. The capillary network outside the bone has been removed. The graft was both cancellous (with thin metaphysial cortex), on the left, and cortical, on the right.

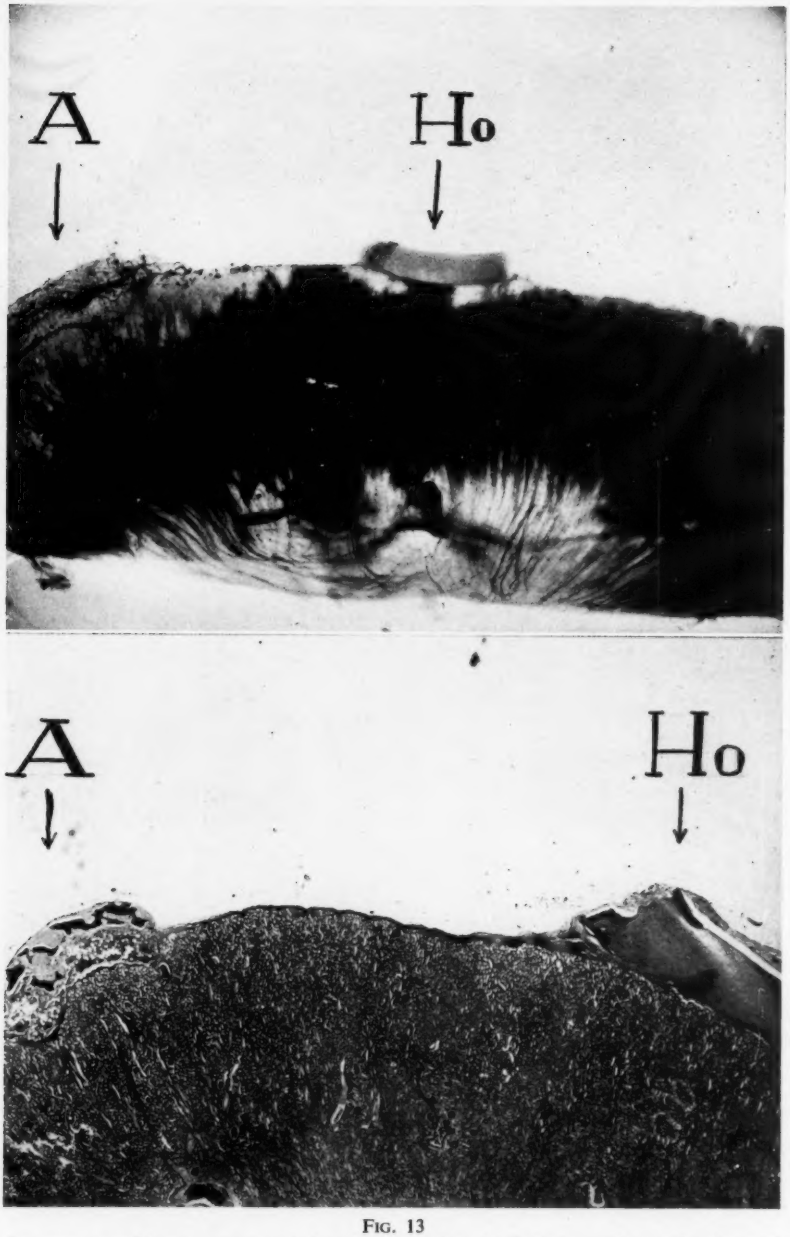

FIG. 13

Autogenous and homogenous cortical grafts twenty-four days after transplant under the renal capsule (×5.). No vessels penetrated in the homograft, whereas the autograft was largely vascularised and well on the way to reabsorption. The capsule had been detached.

At the ninetieth day three specimens were removed. One of the grafts in the femur was still recognisable because of its different refraction, yet it was extensively penetrated by new vessels, and under the microscope extensive osteoclastic and osteoplastic changes were seen. The limits of another graft had already disappeared in the transparent specimens, and were only revealed histologically by a layer of small fragments of old and newly formed bone. This difference in the behaviour of the grafts may be related to their position in the bed: the first graft was implanted near the cortex whereas the second one was buried deeply in the bone marrow.

In the kidney graft a few isolated vessels were found; the histology demonstrated fragments of dead bone with scanty new bone delimiting living haemopoietic marrow.

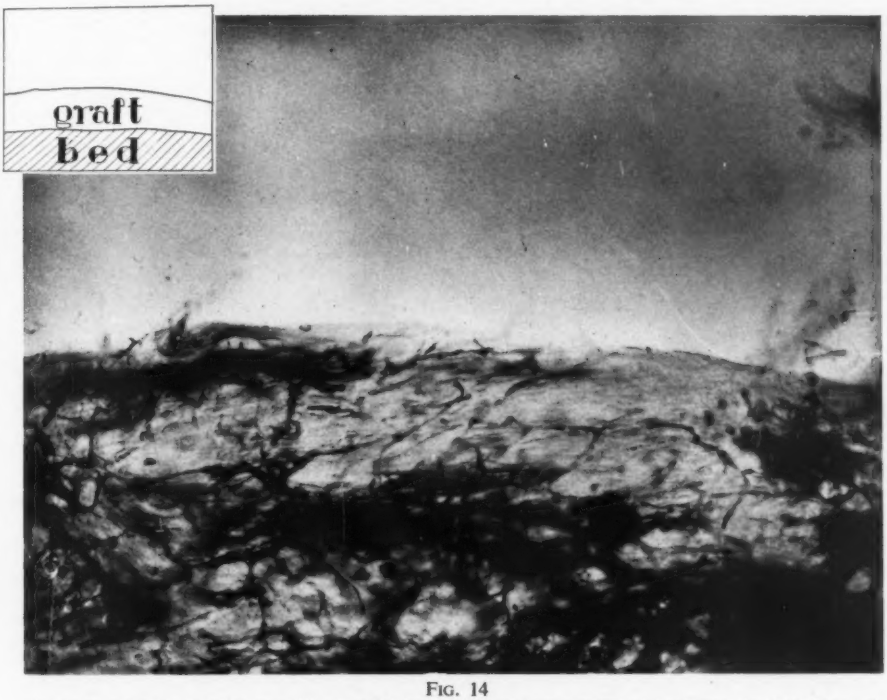

FIG. 14

Autogenous cortical graft two millimetres thick fifty days after transplant on to femur. (×10.) The graft is largely crossed by vessels. Its position, at the level of the normal cortical bone corresponding with the one normally occupied by the cortex, seems to facilitate new appositional growth inside and around it instead of causing complete reabsorption.

Summary of the vascularisation of autogenous grafts—If the architecture of the cancellous graft had a relation to the bed which favoured vascular penetration, a substantial number of vessels might be seen as far as three millimetres inside the implant after *seven days*; if there was an obstacle to the vascular penetration a delicate network of vessels appeared in the bed and at first only some isolated vessels penetrated the graft at this stage. At *one month* grafts five millimetres thick placed in the femur were reached everywhere by the new vessels. Towards the *thirty-fifth day*, with the exception of the regions situated farthest from the bed, they showed a vascular pattern already almost indistinguishable from normal. Gradual reabsorption of the necrotic bone and some appositional growth, together with the replacement of the granulating tissue by means of haemopoietic marrow, completed the normal picture. The cortical bone was completely pierced at the twenty-first day and disappeared at the ninetieth. Inconstant results were obtained with the renal grafts probably due to the different circulatory patterns of the two beds.

HOMOGENOUS GRAFTS

Cancellous bone—Caution was necessary in sectioning the specimens after *one week* because the bone was so weakly adhered to its bed that it became easily detached; it appeared uninjected and had very sharp borders in contrast with the intensely injected surrounding tissues. Very delicate capillary networks limited the periphery of the graft (Fig. 15). The networks were close together, some anastomosing with neighbouring groups and others remaining totally independent. They appeared in intimate contact with the transplanted bone, exactly following its surfaces but even if the intertrabecular spaces were open towards the bed no vessel was ever seen inside the homogenous graft at this stage.

On the kidney a richly vascularised capsule covered the graft but no vessels were seen to penetrate the implant.

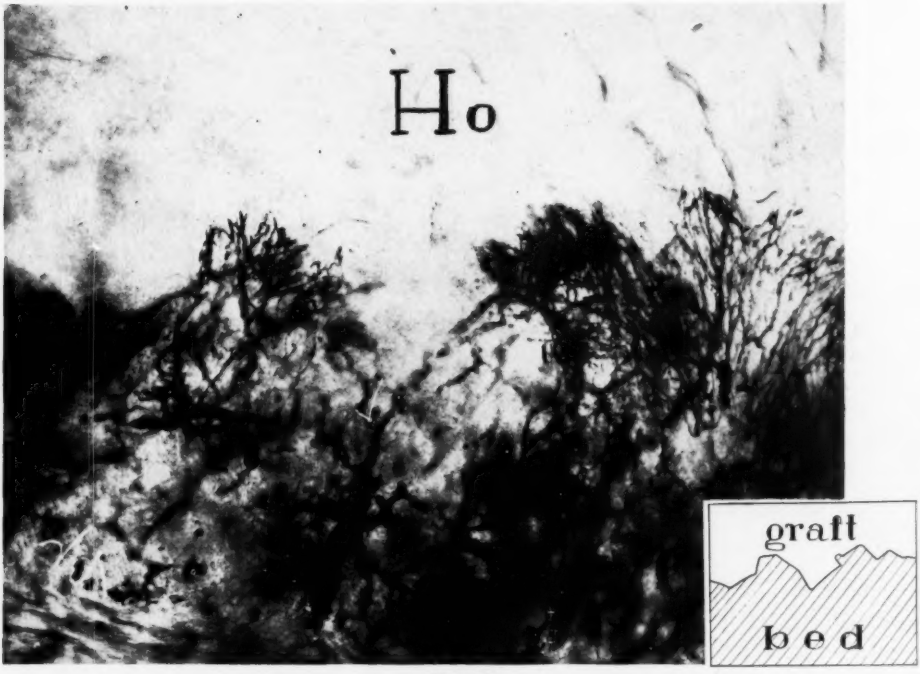

FIG. 15

Homogenous cancellous graft seven days after transplant on to femur. (×40.) The delicate capillary network follows exactly the borders of the graft.

At the end of the second week the graft became less easily detachable during its handling in the laboratory. Twenty to a hundred isolated capillaries and arterioles were found per square centimetre in both femoral and renal grafts. They were coming from the network lining the surfaces and proceeding into the graft for 100–200 microns, and sometimes for half a millimetre. The arterioles frequently divided terminally into two or three branches. On the kidney they were coming either from the capsule or from the subcapsular capillary network.

The homogenous grafts examined from the *twentieth to the twenty-fifth day* were firmly fixed to the bed. Their borders could not be seen by the naked eye. The vascularisation had penetrated two to three millimetres, which was sometimes as much as half of the thickness of the graft (Fig. 16). In other areas the delicate vascular network was still delimiting the

shape of the graft. This had decreased in size when compared with that of the previous examination and already showed a tendency to fibrosis. Large vessels of venous type were observed ending in sinusoids.

On the kidney, a few penetrating vessels were seen in one case and a continuous capsular system of vessels in another, without in either case entering deeply into the bone.

After thirty to thirty-five days some of the grafts placed on the femur were vascularised for three-fifths of their thickness. The regions nearest to the bed had already taken up the normal vascular pattern; elsewhere the vessels showed a tendency to diminish both in number and in calibre. But other areas were completely avascular and appeared encapsulated by fibrous tissue.

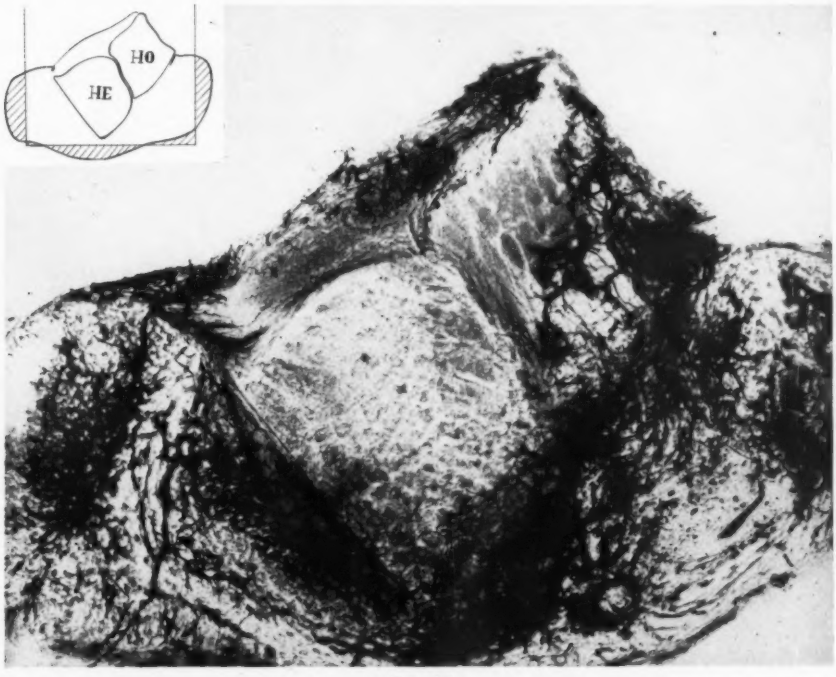

FIG. 16

Homogenous and heterogenous cancellous grafts twenty-four days after transplant on to femur. (×10.) The homogenous graft is vascularised for nearly half of its thickness. The network which encircled the borders still persists. The heterogenous graft has been penetrated by only two vessels, supplying a limited peripheral area; here too it is possible to see the lining network.

On the kidney two of the four grafts were almost entirely crossed by new vessels, but the other two had only a single vessel inside them.

At the forty-fifth day nearly the same pattern was seen. At least two-thirds of the graft showed evidence of a normal vascular arrangement. In some other areas, on the contrary, no vessels were seen, the histological sections demonstrating only necrotic bone and marrow. Sometimes the explanation could be found in a mechanical obstacle due to the position of the graft in the bed; in other cases the reason remained obscure.

More than once the graft was found supplied only by two or three vascular networks (Fig. 17) coming from as many large vessels, which alone penetrated its surface.

After three months both the implants in the femur and the kidney appeared revascularised,

and on histology granulating tissue was found widely distributed with a great deal of dead bone still present.

Cortical bone—*In the first week* a profuse vascular network was noted around the graft. In numerous sections of four specimens, only two narrow capillaries 100 microns long coming from the bed were observed.

In the second week no vessels were seen in the grafts.

After three weeks it was only possible to see six vessels in each graft, placed widely apart from each other. They had penetrated for about 500 microns, approximately one-fourth of the total thickness of the bone graft. A long vessel was found running for about a millimetre parallel to the main surface of the implant, probably following a Haversian canal.

FIG. 17

Homogenous cancellous graft forty days after transplant on to femur. (×45.) The graft occupies all the field. A single vessel pierces the graft and supplies alone a fairly extensive area. This is a common finding in invaded homogenous transplants.

In a graft of the femur after *fifty days* isolated arterioles with few branches were running through the bone from one surface to the other. No vessels were found in the kidney graft. *After three months* the findings were similar. The grafts were still clearly visible in both the femur and the kidney, but they had become narrowed here and there; a poorly vascularised network was present where an osteoclastic process was active. About five vessels were seen to penetrate the implant in the femur; none was seen in the kidney graft which was slightly eroded in a few superficial places.

Summary of the vascularisation of homogenous grafts—*At the first week* the cancellous graft was surrounded by a vascular network from which isolated vessels supplying limited areas had penetrated about 0·5 centimetre in depth after *thirty-five days*. In other areas this network was found gradually to decrease, corresponding to the establishment of a front of osteoclasis

which seemed to slow down the penetration; moreover it was seen to disappear when a fibrous covering encircled the graft, which suggested that there was only slight possibility of further vascular penetration.

Vascularisation of the cortical fragments was always slower and more incomplete.

On the kidney the results either resembled those on the femur or showed even more limited vascular penetration.

HETEROGENOUS GRAFTS

Cancellous bone—*At the end of the first week* the bone was almost entirely free from any organic connection with the bed, an observation which was often made in this type of implant

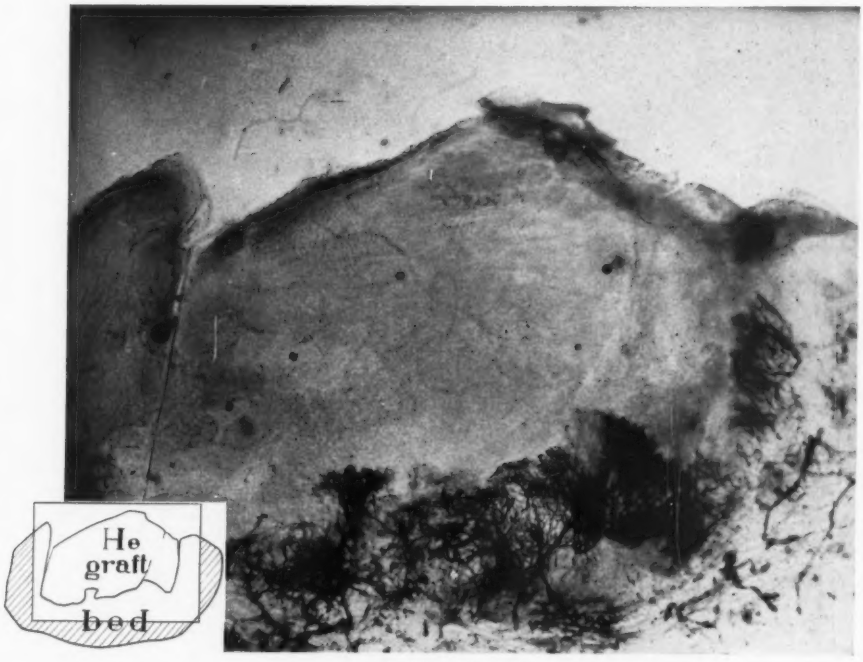

FIG. 18

Heterogenous cancellous graft seven days after transplant on to femur. (×20.) A dense vascular network outlines the graft; the vessels follow exactly the surface of the bone but are separated from it by a thin layer of fibrin and exudate that constitutes a " no man's land " which seems to obstruct the path of the vessels.

even after more than six weeks. The border of the graft was very clearly seen just where the injected vessels ended and where they formed the capillary network already described for the homograft. Here, however, this network appeared even denser and surrounded all the deeper surfaces of the graft (Fig. 18), and it did not touch the bone, being separated from it by a narrow layer of 50–100 microns of exudate and fibrin. In the kidney the same local hypervascularity was found around the grafts and a serous fluid collection was found between the capsule and the graft.

At the second week the findings were the same; a dense network of vessels encircled the graft, but none had succeeded in penetrating its borders.

After twenty to twenty-five days the surface was crossed at a few isolated points in the femoral graft. Where the vascularisation of the bed was profuse some vessels, no more than four or

FIG. 19

Heterogenous cancellous graft twenty-one days after transplant on to femur. *Top*—Transparent injected specimen. (×40.) *Bottom*—Histological section. The upper curved line corresponds to the border of the graft; a peripheral and definitely limited area is vascularised, the vessels getting round the trabeculae. This area corresponds to a massive invasion of young mesenchymal tissue, as the histological section shows.

five in each implant, were seen to penetrate the graft from the femoral bed for a maximum depth of half a millimetre. Each vessel was large in calibre, as it supplied a substantial segment of bone. The vascular tree occupied definite areas spreading round the old dead trabeculae (Fig. 19). Histologically this vascular zone corresponded to a massive penetration of young connective tissues, which succeeded in crossing the border at a single point, while everywhere else the limits of the implant were lined with fibrous tissue spreading inside the graft.

In the renal graft no vessels were found.

After thirty to thirty-five days the findings were similar. An isolated vessel entering for one millimetre, or even less, was seen in two grafts, but none was seen in the others (Figs. 20 and 21).

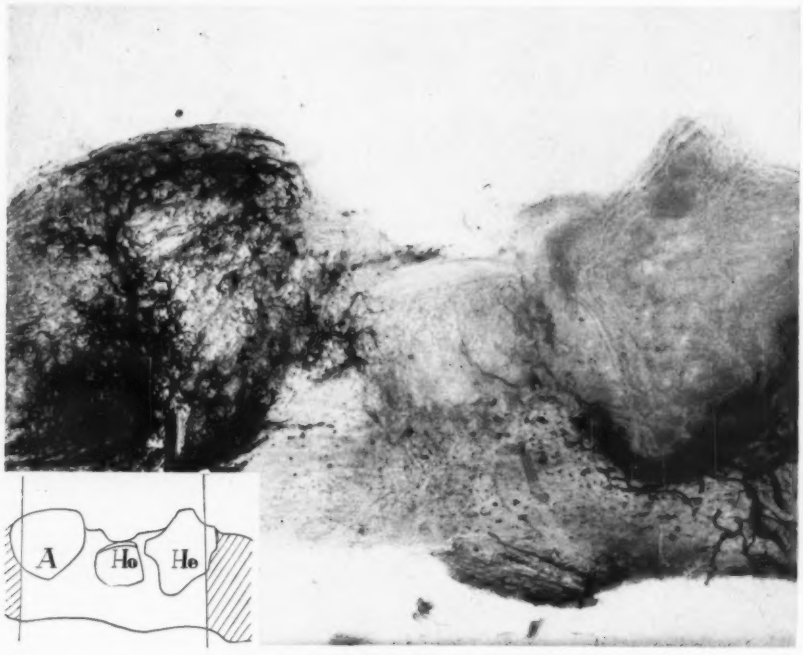

FIG. 20

Autogenous, homogenous and heterogenous cancellous grafts thirty-three days after transplant on to femur. (×5.) Whereas the autograft is almost completely traversed by vessels, only the left side of the homograft is penetrated in isolated areas, and the heterograft is still lined by a non-penetrating hyperaemic network.

At forty-five days slightly greater penetration was seen, although it was always restricted to very limited areas (Fig. 22). If the cancellous bone of the graft was covered by a thin cortex a definite capsule of fibrous tissue surrounded the bone, and no vascular network was ever seen.

After three months, in the more favourable grafts, the vascular penetration could be seen to cover from about one-third to half of the entire graft, together with a gradually invading connective tissue. Nevertheless, one graft on the femur was seen to be completely deprived of vessels at this stage.

Cortical bone—*After ten, twenty and thirty days* there was no, or very slight, adherence of the implant to the bed; the usual vascular network was found around the graft in the three first weeks, but no vessels had penetrated inside it.

After two months the radiographs showed all the three fragments intact, with a surrounding osteoporosis of the bone bed; in the femoral grafts the implants were excluded by a fibrous capsule, without any peripheral vascular network.

After three months, still no vessel was observed inside the graft, and only a few vessels around it, corresponding to a limited area of osteoclasis.

Summary of the vascularisation of heterogenous grafts—*After twenty to twenty-five days* some isolated vessels coming from a peripheral dense capillary network penetrated the cancellous graft for half a millimetre. In the *following months* the vessels proceeded for a further half

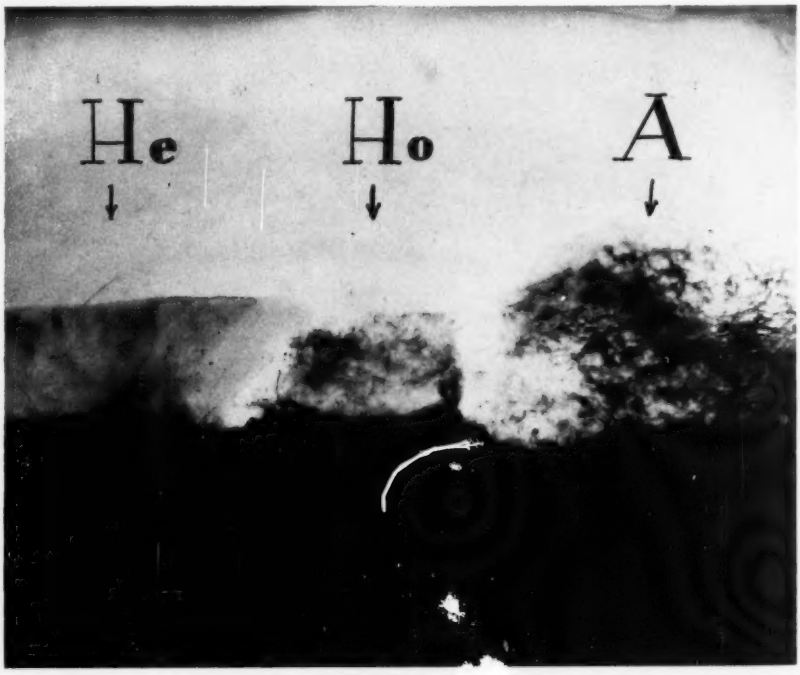

FIG. 21

Autogenous, homogenous and heterogenous cancellous grafts thirty-five days after transplant under renal capsule. (×10.) The capsule has been stripped off. The autograft is completely penetrated and is far advanced in its rearrangement; the homograft is fairly well penetrated; but the heterograft is completely lacking in vessels.

millimetre in a few areas; while the greatest part of the graft was not vascularised, and often definitely excluded by a layer of fibrous tissue. No vessel was found inside any of the cortical grafts even as long as three months after their implantation.

DISCUSSION

Some important differences were found to exist in the form of vascular penetration of autogenous, homogenous and heterogenous transplanted bone, both as regards the rate of penetration and the pattern of the new vessels (Figs. 20 and 21).

A cancellous autogenous fragment five millimetres thick may be completely vascularised in *twenty to twenty-five days* whereas the homogenous grafts of the same thickness showed at the most a vascularisation of only three-fifths after *thirty to thirty-five days*. Moreover the rabbits used for this investigation have been inbred for a long time and may have attained

a certain amount of tissue affinity. The heterogenous grafts followed up to three months after implantation never showed any appreciable vascularisation.

The pattern of the new vessels is likewise quite different in the three types of implant. A capillary network surrounds the implant during the *first week* in the homografts and the heterografts but is seen only very occasionally and for a very short period in the autograft. It represents the vascular response to a mechanical barrier comparable to that of the articular or epiphysial cartilage implanted with the graft. The capillary network is directly attached to the bone in the autografts and homografts; in the heterografts it is separated from it by a layer of fibrin and inflammatory cells and becomes a sort of " no man's land " which is very difficult for the vessels to cross.

FIG. 22

Heterogenous cancellous bone forty days after transplant under renal capsule. (×70.) From the capsular vessels running on the surface of the graft one isolated branch penetrates perpendicularly into it for about 400 microns.

The present findings emphasise once again the importance of the " schleichender Ersatz " claimed first by Barth (1895) and later by Phemister (1914) in its literal translation of "creeping substitution." But while this process plays a most important part in the rehabitation of the autogenous graft, where the vessels usually penetrate singly accompanied by few connective mobile cells and frequently rest directly on the dead bone (Fig. 23), its importance decreases in the homogenous, and even more in the heterogenous, implants. In the homogenous graft many areas seem resistant to the penetration of isolated vessels from the bed, and a frontal invasion is often required; the latter is almost the rule in the heterogenous graft, where the piercing vessel must be accompanied by a considerable amount of granulation and bone-removing tissue. In the autograft penetration is immediate, following the entire surface of contact; in the homograft it takes place after a quiescent period of ten to fifteen days, and only in selected regions; in the heterogenous graft the latent period is of twenty to twenty-five

days, but it is not uncommon to find that, after three months, only a small vessel penetrates the implant for a total surface of two square centimetres.

Already after twenty days it is possible to see the initially invaded areas of the autogenous bone return to a normal vascular pattern. At least fifty days are necessary before this happens in the homogenous bone, and it never was noted to occur in the heterogenous implants.

To summarise: vascularisation is quick and complete when the graft is placed in a good bed such as the femoral metaphysis; it is two to three times slower and incomplete in the homograft; it is extremely slow (six or more times) and absolutely limited in the heterograft.

We paid a good deal of attention to the possibility, so often mentioned by many investigators from Phemister (1914) and Albee (1915) to Nageotte (1922), of an immediate

FIG. 23

Autogenous cancellous graft twenty-four days after transplant on to femur. The injected vessels are seen advancing almost completely alone in the marrow space between the trabeculae. Some are adherent to the bone, having left behind the new connective tissue, and one of them is seen in the subchondral layer surrounded by some living osteocytes.

recanalisation of the pre-existing vascular system of the implant, at least in the autograft. We could not find any indisputable evidence of this process. A cortical fragment, two millimetres thick, was found after seven days completely perforated from one surface to the other by some vessels; but the smallness of the distance covered does not exclude the possibility that it was in fact a new advancing vessel, because the average speed of penetration for an autograft in good position was several times proved to be about two to three millimetres a week; in that case a pre-existing canal may have contributed to this penetration. The same may have happened with the three millimetres thick fragments found completely vascularised, one after ten and the other after twenty-one days. Unfortunately we never found an injected vessel at the first week at a distance greater than three millimetres from the bed. A broad

capillary network was observed more than once in the subchondral space of grafted bone that included some joint cartilage just beneath the calcified layer of the cartilage; the network was quite far from the bed and from the granulating tissue and was surrounded by trabeculae with some definitely living cells. Considering all these facts together, and particularly the finding at an early stage of such a differentiated vessel as a capillary juxtachondral loop, recanalisation of the pre-existing vessels could be assumed. But, on the other hand, if the suggestion by Abbott *et al.* (1947) that a cell of a graft could survive for fifteen days without blood supply is true, we may assume that a new vessel could have reached the pre-existing bone canal, and been transformed into a sinusoid in time to allow the local osteocytes to recover.

SUMMARY

1. The rates of vascularisation in 119 autogenous, homogenous and heterogenous bone grafts, placed in the femoral medullary cavity and under the renal capsule of rabbits, were studied.
2. Substantial differences have been found in the speed of vascular penetration and arrangement among autografts, homografts and heterografts: penetration of the heterogenous implant was six or more times slower. Moreover, large areas of the homografts and heterografts were often totally excluded from the circulation for as long as the research was continued (up to three months). Revascularisation of the cortical bone was slower and less profuse than in cancellous bone, keeping always the same respective proportion between the three types of bone we have described. The results on the kidney were much less constant, and I attribute this to the vascular peculiarities of the bed.
3. Vascular patterns peculiar to the time of implantation and type of graft are described.
4. Suggestive, even if not totally convincing, evidence was found of recanalisation of old vessels inside the graft by advancing vessels from the bed.
5. There is striking correlation between the rate of vascular penetration of the bone implants and their ultimate " take " or incorporation in the bed.

My thanks are due to Professor J. Trueta, without whose help and encouragement this work would not have been possible. My thanks are also due to Mr D. W. Charles and Mr A. Mann who have prepared the material.

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PROCEEDINGS AND REPORTS OF UNIVERSITIES COLLEGES, COUNCILS AND ASSOCIATIONS

GREAT BRITAIN

BRITISH ORTHOPAEDIC ASSOCIATION

ROBERT JONES CENTENARY MEETING

The spring meeting of the British Orthopaedic Association, held on May 9–11, 1957, under the presidency of Mr Philip Wiles, was dedicated to the memory of Sir Robert Jones and marked the centenary of his birth. It was appropriate that the clinical part of the meeting should have been held at the Robert Jones and Agnes Hunt Orthopaedic Hospital, Oswestry, which was founded by these two pioneers whose names it now bears. A full report of the meeting will be published in the August number of the Journal.

TRAVELLING FELLOWSHIPS IN ORTHOPAEDIC SURGERY

from Great Britain and the British Commonwealth to the United States of America in 1958

Applications are invited from Fellows, Members and Associates of the British Orthopaedic Association, whether resident in Great Britain, Ireland or elsewhere in the British Commonwealth of Nations, for election as Travelling Fellows to visit orthopaedic centres in the United States of America and Canada for an eight-week tour (including the time of transatlantic travel). Four Travelling Fellows will be appointed by the president of the British Orthopaedic Association on the recommendation of the Executive Committee. In the election, preference will be given to senior orthopaedic registrars and surgeons who have gained orthopaedic consultant appointments within the last few years. The party will probably leave this country early in May and return at the end of June.

Twenty typewritten copies of the application should reach the secretary of the British Orthopaedic Association, 45 Lincoln's Inn Fields, London, W.C. 2, not later than November 1, 1957, stating name, address, telephone number, age, qualifications, medical school, and present appointments, together with an outline of previous experience and academic or literary achievements. The application must be supported by a referee who is a Fellow of the Association. Short listed candidates will be interviewed in London on December 6.

If any young surgeon who is not already an Associate of the British Orthopaedic Association wishes to apply, he should communicate with the secretary of the Association at 45 Lincoln's Inn Fields, London, W.C. 2 (HOLborn 3474), who will send the necessary forms.

SCIENTIFIC SOCIETIES AND REGIONAL ORTHOPAEDIC CLUBS

THE BONE AND TOOTH SOCIETY

At a meeting held at the Institute of Orthopaedics on June 14, 1956, with Dr H. A. Sissons in the Chair, the following communications were made.

The value of bone biopsy to the surgeon—*Mr J. Rowland Hughes* (Oswestry) recalled that bone biopsy provided a method of studying the microscopic anatomy of either a localised bone lesion or the general skeletal structure. The anatomical approach had to be planned and could be facilitated by using small mechanically propelled trephines under radiographic control; pencil grafts of different portions of the lesion could thus be obtained. Differentiations between *a*) tumour or infection, *b*) chronic or pyogenic infection, *c*) tumour or reticulosis, and *d*) benign or malignant tumour, primary or secondary, were illustrated. Special point was made of the differential diagnosis in cases of wedge collapse of vertebral bodies. Bone biopsy might distinguish between malacia and porosis. More evidence was required relating histological appearances with age.

Calcium exchange in vivo—*Dr K. B. Dawson* (London) said that an experiment in which both live and dead limbs of a living animal were perfused with an isotomic solution containing ^{45}Ca had established that Ca ions in the bone crystals were exchangeable in the live limb by both metabolic and ionic exchange processes, and in the dead limb only by the latter. Initially the exchange processes predominated. The percentage of exchangeable Ca was greatest in areas of new bone and active

growth. These areas were also shown to be more vascular by the technique of C. Begg (Dunedin) in which a radio-opaque dye was injected into the medullary cavity. It had not proved possible to establish an exact relationship between the exchange and metabolic processes.

The relationship between age and the fluorine content of human bones and teeth—*Mr D. Jackson* and *Dr S. M. Weidmann* (Leeds) said that fluorine had been estimated in dry fat-free cancellous rib-bone from cases of sudden death, and in caries-free premolar teeth, all from people born and bred in Leeds, a non-fluorine area. Bone fluorine content showed a linear increase with age (variation from line 50 per cent) from 45 milligrams/100 grammes at ten years to 230 milligrams/100 grammes at eighty years. At eighty years, therefore, normal fluorine content lay between 115 and 345 milligrams/100 grammes. The skeletal tolerance to fluorine had been stated to be about 400 milligrams/100 grammes. The fluorine content per 100 grammes of dry fat-free dentine increased from 12 milligrams between six and fourteen years to 40 milligrams between sixty-four and seventy-six years. It remained static up to fourteen years, rose sharply to thirty years, and then increased much more slowly. Enamel fluorine content (6–10 milligrams/100 grammes) increased slightly from six to twenty years, and then changed little.

Insensitivity to calciferol developing during treatment of various forms of metabolic rickets and osteomalacia—*Professor C. E. Dent, Miss C. M. Harper* and *Mr G. R. Philpot* (London) recalled that it had already been shown that patients being treated for post-operative hypoparathyroidism could develop insensitivity to calciferol after some years but still respond normally to another form of vitamin D. This phenomenon had also been observed in various forms of metabolic rickets and osteomalacia. Four patients (resistant rickets; severe osteomalacia in an adolescent; Lignac-Fanconi disease, with cystinosis; adult Fanconi syndrome) were described with clinical, radiological or calcium balance evidence of an excellent response to calciferol when first treated. After two, one, three and five years respectively their bone disease returned, unchecked by larger does of calciferol. In all cases a change to AT10 caused rapid improvement. It was hoped that treatment of all such cases might in future be improved by changing from time to time the form of vitamin D administered. It seemed possible that the actual disease process in these cases might be an exaggeration of vitamin D insensitivity.

NORTH-WEST METROPOLITAN ORTHOPAEDIC CLUB

A meeting of the North-West Metropolitan Orthopaedic Club was held on December 8, 1956, at the West Middlesex Hospital, by the kind invitation of Mr E. A. Devenish. Fifteen members were present. *Mr L. C. L. Gonet* showed the following cases on behalf of *Mr Devenish*. 1) A patient with a tuberculous lesion of the second lumbar vertebra. 2) A case of paraplegia following an injury to the spine at the level of T.3–4. 3) A case of osteoarthritis of the left hip treated by Charnley's intrapelvic stabilisation. 4) A malignant synovioma of the left wrist. *Dr B. E. C. Nordin* gave a stimulating talk on the biochemical findings in osteoporosis and allied diseases.

EAST ANGLIAN ORTHOPAEDIC CLUB

A meeting of the East Anglian Orthopaedic Club was held at Addenbrooke's Hospital, Cambridge, on December 1, 1956.

Congenital anomalies—*Mr T. J. Fairbank* showed first a patient with osteogenesis imperfecta. He pointed out that the sclerotics were not blue as in the familial type. His second case was one of congenital bowing of the radius and ulna and of the femora on both sides with poor ossification of the skull. Later, metaphysial defects developed in several areas. He suggested that it might be an example of Ollier's disease.

Diabetic neuropathy—*Mr K. Swinburne* showed a case of diabetic neuropathy treated by Lisfranc's amputation. He pointed out the importance of suturing the extensors of the toes to the plantar muscles to prevent equinus deformity.

Unusual cases of fracture of the fibula in women—*Mr I. H. Sayani* showed two unusual cases of fracture of the fibula, with dislocation of the ankle, needing open reduction. They were associated with some paresis of the anterior tibial muscles and ischaemia of the extensor hallucis longus followed by contracture.

Arthrodesis of the ankle and subtalar joint—*Mr L. W. Godfrey* showed a method of arthrodesis of ankle and subtalar joints used in cases of paralytic flail foot, arthritis, and disorganisation after injuries. A graft was taken from the whole thickness of the fibula and driven through both joints from the sole. Afterwards the patient was fitted with a boot with a rocker sole.

Osteomyelitis of tibia—*Mr Sayani* gave a progress report on a case shown to this society six years ago. The patient had osteomyelitis of the tibia leading to partial fusion of the epiphysis of the lower end of the tibia. As growth had proceeded a valgus deformity had developed which had been corrected by osteotomy of the tibia. Since then, however, uneven growth had continued and the deformity was recurring. In discussion the value of a second osteotomy and of stapling of the inner side of the tibial epiphysis were considered.

Unusual conditions in femur—*Mr W. Butler* showed two cases of " cystic " changes in the neck and base of head of the femur in healthy men. The joint surfaces appeared normal. The lesions were removed and the cavities were packed with bone chips. On section one was found to be an intra-osseous fibroma and the other a benign synovioma or lymphoid granuloma.

Dislocation of hip with fracture of head of femur—*Mr Godfrey* reviewed six cases of dislocation of the femur with a fracture of the lower part of the femoral head. He discussed the mechanism by which the injury had occurred and advocated open reduction. All those that were treated conservatively had necrosis of the head and arthritis.

ITALY

TRIBUTES TO ROBERT JONES AND VITTORIO PUTTI

We print below two of the speeches made at the banquet in Florence on the occasion of the visit of the British Orthopaedic Association in October 1956. *Professor O. Scaglietti*, Professor of Orthopaedic Surgery in the University of Florence, said:

Ladies and Gentlemen, dear Friends—The end of your trip to Italy is at hand, and I hope you will remember it with pleasure, and that you may repeat it in the future. So that I say to you to-night not " goodbye," but " arrivederci."

That you have come to Italy shows how alive and deep are the bonds that unite the English and Italian Schools of Orthopaedic Surgery. These bonds were laid down by two great teachers, Sir Robert Jones and Vittorio Putti, who built our speciality on such solid foundations in England and in Italy. Sir Robert Jones, a great organiser as well as a great surgeon, created the solid basis on which British Orthopaedic Surgery rests to-day. It is likely that in part his fundamental principles and surgical practice were influenced and inspired by Vittorio Putti, who was as versatile as he was brilliant. In the same way Italian Orthopaedics benefited from the influence and ideas of Sir Robert Jones.

I doubt if there has ever been a more fruitful friendship than that between Sir Robert Jones and Vittorio Putti. Though they were of such different temperaments, the deep spiritual understanding which existed between them had a profound and reciprocal influence on the development of English and Italian Orthopaedics. I remember with what affection and admiration Vittorio Putti always spoke of Sir Robert Jones, and I can still see his sad face when he received the sudden and unexpected news of Sir Robert's death.

During my visit to England last spring I was greatly impressed by the depth to which the spirit of these two great teachers had penetrated, and how much of that spirit was still alive. Wherever I met the pupils of Sir Robert Jones I found them jealous custodians of the fundamental principles and teachings of their great teacher.

In getting acquainted with these pupils, in following their work and in discussing problems of orthopaedic surgery with them, I did not feel that I was meeting colleagues for the first time. In Liverpool, particularly—perhaps I may be excused for singling out the home of Sir Robert Jones—I felt I was among old friends whom I had known for years; since, in fact, I took my first steps in orthopaedics. It was as if I had always lived by their side, so strong was our spiritual affinity. I found they had the same method of discussing clinical cases, the same prudent way of approaching the question of surgical intervention, the same critical analysis of the results. Just as some of Sir Robert's pupils felt themselves indirectly to have learned from Vittorio Putti, so I felt that I could also consider myself a pupil of Sir Robert Jones, though I never had the good luck to know him.

It is a rare destiny reserved only for few and very exceptional men that they shall continue to live for ever—immortal in the spirit and in the work of their pupils.

It is good to think that the ideals which these two men held so enthusiastically and to which they dedicated themselves, are still strongly adhered to. Away back in 1924, thirty-two years ago, the British Orthopaedic Association and the Italian Orthopaedic Society met in Bologna; they numbered about twenty representatives. To-day their membership runs into hundreds, and during your visit here you have been able to judge the vitality and completeness of our institutions. I thought that something tangible should remain of this reunion, something that would demonstrate the

spiritual union of our teachers, so I have prepared a bronze medal for you which shows them united in death as they were in life. I feel certain that from this present meeting, the bonds which have united our Societies will be still further reinforced to the enduring good of our speciality.

And now I invite you to drink with me a rather unusual toast. With gay hearts let us drink to the memories of Sir Robert Jones and Vittorio Putti, and as we drink let us wish for an even greater and enduring future for the British Orthopaedic Association and the Italian Orthopaedic Society.

Professor Bryan McFarland, Professor of Orthopaedic Surgery in the University of Liverpool and past president of the British Orthopaedic Association, said:

Mr President, Professor Scaglietti, Senore Scaglietti, Ladies and Gentlemen—I have been given the privilege of paying tribute to the life and work of Vittorio Putti. It is a great honour and a great responsibility, yet at the same time it is a very keen pleasure.

While a man is alive his stature may appear very great, but after his death it may in retrospect appear less. This is not true of Vittorio Putti. In his life he was undoubtedly a great figure in the surgical world and the importance of his life and work has not been diminished, rather has it been enhanced, by the passage of time. By character studious, ingenious and wise, he had a personality which combined distinction and nobility with a very handsome and impressive appearance. Thus he carried everywhere with exquisite perfection the clinical reputation of the Istituto Rizzoli and the long academic history of the University of Bologna.

I first met Vittorio Putti in 1927. He came to Liverpool to deliver the Lady Jones lecture. He was, as it were, the first "external" lecturer to be appointed. The Lady Jones lecture was established in 1923 in honour of Sir Robert Jones, but since he was still alive, the lecture, which was to be given every second year, was named after Lady Jones who had died some years previously. Sir Robert himself gave the first lecture in 1925. So it was in 1927 that Putti lectured in the University of Liverpool. His subject was " Sciatic Scoliosis " and it is of considerable interest to-day that he attributed this syndrome to pressure on the roots of the nerves of the sciatic plexus and he fixed the site of pressure as the intervertebral foramen. I cannot help remarking that he would be very satisfied to know how near he was thirty years ago to what we regard as the truth to-day.

The friendship between Robert Jones and Vittorio Putti was very close and very real. They met often and they exchanged ideas. And therefore, although I saw Putti only a few times after 1927, I knew him well from the remarks and the conversation and the teaching of Sir Robert Jones, to whom I was at first a pupil, and later a very junior assistant for some seven years.

It is commonplace to say that Putti built Italian orthopaedic surgery. But what is not so obvious, although it is certain and undoubted, is that British, European and American orthopaedic surgery stands in heavy debt to his adventurous but careful mind and to his progressive but sound surgery. It would be difficult to estimate how many young men went from the Rizzoli Institute to practise his teaching in all parts of the world. In addition, it would be difficult to exaggerate the number of young men who, through Sir Robert Jones, also benefited from the ideas and teachings of Vittorio Putti. Yet nevertheless this indirect effect is no less real and no less important.

Putti's death in 1940 was a great loss. But he left behind him riches beyond the price of any precious jewels, for he left his pupils with his store of knowledge and of wisdom, and he left them with a steady faith and with his own burning zeal to do good to his fellow men.

It seems to me, in honouring this great man, that it would be only fitting if I were to try to say a few words in his own beautiful language. Perhaps you will bear with me for a moment while I do this, and at the end I shall propose that we drink to his immortal memory.

Parlo con gratitudine e con amicizia. E per me un grande honore di commemorari qui l'insigne Maestro Vittorio Putti—il primo, il grandissimi ortopedico—un imperituro simbalo di devozione all'umanita. Fu uomo della mente eclectica, originale, e creativo: un estudioso e bibliofilo; fiero, bello, come un principe del renascimento. Fu un re per i suoi malati;—un re per me giovanne. Somo lieto e fiero di invitar'vi a brindare alla sua memoria immortale.

BELGIUM

BELGIAN ORTHOPAEDIC SOCIETY

At its general assembly in November 1956 the Belgian Orthopaedic Society decided to create a new category of member: the foreign associate member. Foreign surgeons applying for this membership and introduced by two titular or corresponding members are eligible. Applications, including a curriculum vitae, should be addressed to the General Secretary of the Society, Dr F. A. Poncelet, 62 Avenue de la Toison d'Or, Brussels.

The foreign associate members will enjoy the same rights and pay the same subscription as the Belgian associate members. The subscription is fixed annually by the general assembly and amounts, for 1957, to 900 Belgian francs. The subscription is reduced to 700 Belgian francs for those qualified less than ten years.

INTERNATIONAL SOCIETIES

SEVENTH INTERNATIONAL CANCER CONGRESS

The Seventh International Cancer Congress, under the auspices of the International Union against Cancer, will be held at the Royal Festival Hall, London, from July 6–12, 1958, under the presidency of Sir Stanford Cade. Each day of the Congress will be devoted to one selected topic. It will be approached from every aspect—clinical and experimental—and invitations have been sent to distinguished figures in the cancer world to give " Congress Lectures " on some aspect of the chosen theme. The topics selected are : 1) Cancer control; 2) Hormones and cancer; 3) Carcinogenesis; 4) Chemotherapy. Those wishing to submit papers for presentation to the Congress should write to the Honorary Secretary of the Congress at 45 Lincoln's Inn Fields, London, W.C. 2, England.

Book Reviews

OPERATIVE SURGERY. Under the General Editorship of Charles ROB, *M.C.*, M.Chir., F.R.C.S., Professor of Surgery, St Mary's Hospital, London; and Rodney SMITH, M.S., F.R.C.S., Surgeon, St George's Hospital, London. Consultant and Associate Editors: J. Crawford ADAMS, M.D., F.R.C.S., Orthopaedic Surgeon, St Mary's Hospital, London; R. J. V. BATTLE, *M.B.E.*, M.Chir., F.R.C.S., Plastic Surgeon to Queen Elizabeth Hospital for Children, and to St Thomas's Hospital, London; Sir Stewart DUKE-ELDER, *K.C.V.O.*, Ph.D., D.Sc., Ll.D., M.D., F.R.C.S., Director of Research, Institute of Ophthalmology, University of London, Ophthalmic Surgeon, Moorfields Eye Hospital, London; Maxwell ELLIS, M.D., M.S., F.R.C.S., Surgeon to the Royal National Throat, Nose and Ear Hospital, London, Ear, Nose and Throat Surgeon to the Central Middlesex Hospital, London; C. M. GWILLIM, M.D., F.R.C.P., F.R.C.S., F.R.C.O.G., Obstetric Surgeon, St George's Hospital, London, Surgeon, Samaritan Hospital for Women, London; Wylie MCKISSOCK, *O.B.E.*, M.S., F.R.C.S., Neurological Surgeon, National Hospital for Nervous Diseases, Queen's Square, St George's Hospital, and Hospital for Sick Children, Great Ormond Street, London; and Robert Guy PULVERTAFT, M.B., B.Chir., F.R.C.S., Orthopaedic Surgeon, Derbyshire Royal Infirmary, Surgeon, Harlow Wood Orthopaedic Hospital. 11 × 8½ in. London: Butterworth & Co. (Publishers) Ltd. Price per volume £5, 10s. Index £2.

Volume I. Introductory, Surgery of Trauma, Abdomen (part), with twenty-three contributors. Pp. xviii+135, with many figures. Index. 1956. Volume II. Abdomen (completion), with twenty-two contributors. Pp. xii+137–543, with many figures. Index. 1956. Volume III. Rectum and Anus, Thorax, with twenty-four contributors. Pp. xii+215, with many figures. Index. 1957.

This promises to be one of the really great books on surgery, and judging from the early volumes will fill adequately and completely a gap in our surgical literature.

The authors suggest that the best way of learning how to perform an operation is to watch or, better still, assist an acknowledged master carry out the procedure. If this is accepted, and of course it is, the emphasis in a book of operative surgery must certainly be visual. In this book each operation is described in pictures, stage by stage, and the text is short and used solely for the purpose of clarification, and to indicate difficulties and hazards in the various steps of the operation. The policy of the editors is "to include all operations which a surgeon working on his own in an isolated community might have to perform."

The work is under the general editorship of Charles Rob of St Mary's and Rodney Smith of St George's, with a consultant and associate board of seven well known surgeons in the special branches of surgery. The actual contributors form a heterogeneous collection of well known and lesser known surgeons.

The first volume has an introductory chapter on general technique containing hints on such matters of interest as ligature and suture material, the use of retractors, methods of dissection and preparation of the skin. This may be of some value to surgeons working on their own.

The second part describes the surgery of trauma, and among its brighter sections those on the local care of burns and on genito-urinary injuries stand out. The section on burns is extremely well illustrated. It is extraordinary how much is told of the care of burns in so few pages, but every word counts. In the section on injuries to bone and joint one is sorry to see an illustration of skeletal traction on a fractured femur obtained by a supracondylar pin even though it is stated that the tibial site is preferred for the pin. Surely it must be in very exceptional circumstances that skeletal overhead traction through the olecranon is used for a simple fracture of the humerus. The sections on injuries to the genito-urinary tract and to the face and jaws are well done and thoroughly up to date.

The third and last part of the volume is on the abdomen and, in its introduction, there are parts on the surgery of access, exploration of the abdomen, and a specimen anastomosis of hollow viscera, which presumably are included for completeness. The next and last section of this volume is devoted to the surgery of the stomach and duodenum. It is difficult to imagine the surgeon in an isolated community doing a gastroscopy, but here at any rate he is given some advice on the subject. Fortunately he is told how to diagnose a tear or a perforation of the oesophagus.

One hardly recognises pyloromyotomy for our old eponymous friend, the Rammstedt, but the

subject is well described and discussed. One even gets a choice of five incisions to reach the pyloric stenosis. Gastrostomy is fully dealt with, and it is perhaps wise in view of the possible readers that six methods are described, though the last is " not recommended for human subjects "! The Senn and Witzel methods are described first, and rightly so, even though the right of Senn to the method bearing his name has been challenged—and successfully—in this book by a much more modern surgeon!

The popular and valuable " Balfour " gastrectomy for duodenal ulcer is described, and surely this description must be the next best thing to seeing a master surgeon doing it, for there are no less than twenty-six pictures of the operation so that the stages may be followed easily by the veriest tyro. A useful section is included too on the bleeding peptic ulcer. If no obvious cause is found, the lesser curvature is palpated between thumb and finger. " The tiny bristle-like projection of a vessel into the base of a subacute ulcer may thus be felt." May be! " The available evidence indicates that vagotomy is the operation of choice for gastro-jejunal ulceration " followed by resection (p. 130), but this is not mentioned in the section for the treatment of this troublesome complication (p. 102).

In the second volume the operations on the abdomen are completed in seven sections. The first section describes the treatment of all forms of hernia, starting with diaphragmatic types. The hiatus type may be attacked from the thoracic approach or the abdominal; and the descriptions here are, appropriately enough, by a thoracic surgeon and a general one. Both look easy as portrayed, which they may not be, but no guidance is given as to which is preferable. It is stated by the thoracic surgeon that the question is " still a matter for debate," though it is apparent that he doubts whether the hernia can be satisfactorily repaired through the abdominal route and the reviewer is in agreement. Other forms of hernia, including the obturator and other rare forms, are adequately dealt with.

There are some excellent descriptions of the treatment—and much more—of portal hypertension by a master of the subject. Transportal venography, spleno-renal anastomosis and porto-caval anastomosis are so beautifully illustrated and described that it looks almost too easy and one only hopes that the poor isolated surgeon does not attempt it.

The surgery of the pancreas and the biliary system are fully discussed and illustrated more perfectly than in any previous book. As an example, pancreatico-duodenectomy has twenty-six wash-line drawings, two to the page, and very well described in the letterpress. The more uncommon neo-natal obstructions are discussed from the diagnostic and pre-operative point of view furnishing the reader with details of this most useful aspect of the condition.

The last two sections in this volume deal with operations on the small and large bowel. There can be few conditions omitted in this interesting section. Perhaps a warning should be given to the young surgeon that in doing a colostomy there is a grave risk in withdrawing the thin-walled distended caecum from the wound, because it bursts easily and may thus nullify what is, when carefully done, a life-saving operation. The operations on the bowel are more or less standardised, and are fully described here with attention to many important details that are so essential. It is good to have the value of the Paul-Mickulicz method of partial colectomy emphasised, as was done by Gordon-Taylor during the war. It proved a life-saving method after devitalisation of the bowel by high-velocity missiles.

This second volume gets down to the more common abdominal surgery and is so well done that there can be no criticism—rather praise for an excellent bit of work.

The third volume of this outstanding work has now appeared. It describes in pictorial form operations on the rectum and thorax. There are few operations in these areas that come to the orthopaedic surgeon, but it is the belief of many, among them the reviewer, that the specialist should have a considerable knowledge of what goes on in all parts of the body for his own sake, the sake of his patient and particularly for the sake of his students. Here we have a very fine way of learning this and, indeed, a very easy way.

Many of the non-malignant conditions of the rectum and anus are everyday operations, and here one may read all the best ways of treating such conditions as fissure, haemorrhoids, ischio-rectal abscess and pilonidal sinus. In regard to the last troublesome condition it is wisely pointed out how important it is to obliterate the dead space by penetrating the periosteum with the skin stitches. To obliterate a dead space is often the difficulty in orthopaedic surgery in dealing with a bone cavity. There is there, however, no such easy method but here, too, the author points out the necessity sometimes of packing the wound and leaving it to granulate from the bottom.

In the fifth part of the book, operations on the thorax are described by about eighteen authors. It reaches a very high level, however, and lack of uniformity is not evident. All the notable congenital conditions are adequately dealt with. The various methods of dealing with coarctation of the aorta are described, and delightfully shown in very beautiful line wash pictures. So also is the patent ductus described. The old method of ligation is now considered unsurgical, but it is still carried out apparently by " some surgeons." A simplified operation of pericardectomy is described and no attempt is made

to free the constriction round the great veins. An interesting route to drain the pericardium in suppurative pericarditis is described through the inferior route through the rectus sheath and through the gap between the xiphoid and costal portions of the diaphragm.

This volume is just as good as the other two.

This is an operative text-book that will be of immense value. It is beautifully illustrated and produced—indeed it is one of Butterworth's best—and, though there is a lack of uniformity about it, this is understandable where there are so many contributors. The following volumes are eagerly awaited.—Walter MERCER.

OUTLINE OF FRACTURES INCLUDING JOINT INJURIES. By John Crawford ADAMS, M.D., F.R.C.S., Consultant Orthopaedic Surgeon, St Mary's Hospital, London, and St Vincent's Orthopaedic Hospital, Pinner; Assistant Editor, *Journal of Bone and Joint Surgery*. $8\frac{3}{4} \times 6$ in. Pp. vii+248, with 218 figures. Index. 1957. Edinburgh and London: E. & S. Livingstone Ltd. Price 27s. 6d.

Only a few months after the appearance of *Outline of Orthopaedics* Mr Adams has brought out its companion volume, *Outline of Fractures*. Designed mainly for medical students, general practitioners and physiotherapists, this concise book covers the essential features of all the common fractures and dislocations. The first three chapters contain general information about fractures and dislocations, which has been condensed to a bare minimum. The rest of the book is devoted to injuries of the trunk and limbs. The description of each injury includes the anatomy, clinical features and complications, and is accompanied by exceptionally clear radiographs and well chosen illustrations. The hallmark of a good teacher can be seen in the diagrams, of which Figure 181 is an example.

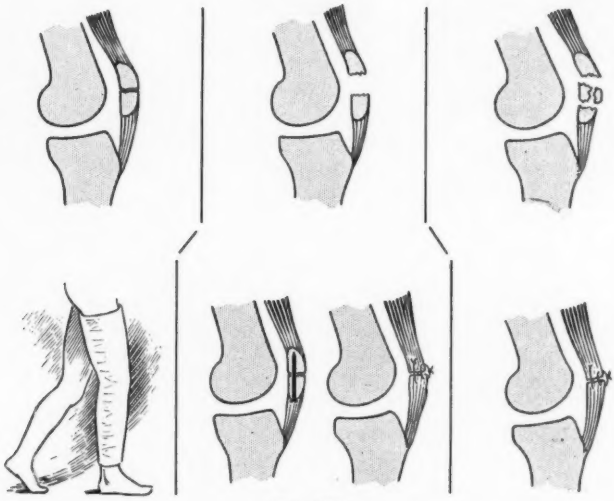

FIG. 181

Fractures of the patella and their treatment. The diagrams in the upper row show the three types of fracture, and those below depict the treatment for each type. 1. Crack without displacement. *Treatment:* Protection in walking plaster. 2. Clean break with separation of fragments. *Treatment:* Patient under forty—Fix fragments with screw. Patient over forty—Excise patella. 3. Comminuted fracture with displacement. *Treatment:* Excise patella irrespective of age.

Modern text-books on fractures and dislocations are large and full of detail. In fact, several of the most popular are very large indeed, and to find the basic essentials devoid of controversy becomes an impossible task for the novice. It is just this information that the student will find in Mr Adams's book. There is a commendable bias towards conservatism, and when operative intervention is advocated the indications are sound and generally accepted.

One would expect an edition of high standard from an author with so much experience as an editor. In fact, the quality of presentation has seldom been surpassed.—L. W. PLEWES.

RELAZIONE AL XLI CONGRESSO DELLA SOCIETA ITALIANA DI ORTOPEDIA E TRAUMATOLOGIA. 1956.

TUMORI DELLO SCHELETRO. By Professor I. F. GOIDANICH, Bologna. 11×8 in. Pp. 606, with 571 figures and tables.

I TUMORI METASTATICI DELLO SCHELETRO. By Professor V. PIETROGRANDE, Rome. 11×8 in. Pp. 386, with 257 figures and tables.

The Italian Society of Orthopaedic Surgery and Traumatology faced the reporters of its forty-first congress, which was held at Bologna in October 1956, with a formidable undertaking when it posed the question " Tumours of the Skeleton." The challenge has been met in an outstanding manner by these two magnificent volumes, which combine to form a complete text-book on malignant disease of bone. They must inevitably be consulted by every surgeon proposing to make a contribution about any aspect of this subject. The production of both volumes is superb; they are printed on fine art paper, and the very many reproductions of radiographs and photomicrographs are by no means the least important contribution.

Primary tumours are dealt with by Professor Goidanich on the basis of more than 2,300 such tumours recorded in the register of the Rizzoli Institute, Bologna, and his report consists in a detailed survey of this material. Both benign and malignant tumours are included, the classification being simple and almost uncontroversial. Each different tumour has a chapter to itself that might well stand alone as a comprehensive review. The same pattern is followed throughout. The chapter opens with a brief historical review followed by clinical, radiological and pathological sections; diagnosis, prognosis and natural history are discussed when necessary, and such problems as incidence and distribution are clearly illustrated by diagrams. The sections on treatment, particularly the indications for different methods, are perhaps less detailed than one would like, but the results are tabulated clearly.

Metastatic tumours are presented by Professor Pietrogrande from the Orthopaedic Clinic of the University of Rome with the collaboration of several other institutes and hospitals. He had a difficult problem in presentation, but it has been well overcome by dividing the work into three parts. In the first he describes the normal structure and biological behaviour of bone, and discusses the factors favouring the successful establishment of metastases. The second part is clinical, and here, after a general statistical analysis, the clinical and radiological behaviour of different tumours are detailed. The third section concerns therapy of every type, from surgery to radio-active isotopes. There is an encyclopaedic bibliography.—Philip WILES.

LECTURES ON ORTHOPAEDICS AND THE RHEUMATIC DISEASES. Edited by Marguerite CLARK; presented at The Scientific Conferences, September 29–October 1, 1955, held in connection with Dedication of the New Building of The Hospital for Special Surgery. 9×6 in. Pp. 182, with many figures. 1956. New York City: The Hospital for Special Surgery. Price $1.50.

The new building to house The Hospital for Special Surgery was formally dedicated in New York on September 29, 1955. This hospital is the distinguished child of the first orthopaedic hospital in the United States, known for so long as the Hospital for Ruptured and Crippled, a name which disappeared in favour of the new one in 1940. The ceremony of dedication was followed by a three-day conference on orthopaedic and rheumatic disorders which was attended by doctors and scientists from the United States, Canada, Europe, Mexico, and South America, and was an outstanding event in orthopaedic surgery in America. Many of the lectures on that occasion are now published for the first time—though in some cases slightly abridged—in this unique volume.

Many international figures in orthopaedic surgery took part in the conference and in this volume we have writings from such well known names as Scaglietti, Judet, Platt and Gallie, besides great Americans like Philip Wilson, Al Shands, Walter Blount and others. And so, even without more said than that, the value of this book can be judged. The volume is in three sections, one on the rehabilitation of the crippled child, a second on clinical problems of orthopaedic surgery, and a scientific section on studies of connective tissue and the rheumatic diseases.

Shands discusses the recent trends in orthopaedic services for the crippled child. He points out that more non-orthopaedic and purely medical problems are being included in the services, with the paediatrician and many other specialists taking more prominent places than in the past. Another trend is the increase in the attention being given to the psychological aspects of the orthopaedic crippled child. An interesting trend is the decline in the population of crippled children in university and metropolitan teaching centres. This is due apparently to the presence of well trained

orthopaedic surgeons in the smaller communities; the children are treated there rather than being sent to university centres, where there is consequently quite a dearth of good teaching material. Platt describes the growth of the residential system for crippled children in England initiated by Sir Robert Jones at Heswall, and later with Agnes Hunt at Baschurch. It is interesting to know that waiting lists for children's orthopaedic beds in England—though he says Great Britain—have almost disappeared.

Paul Colonna describes his modification of capsular arthroplasty for chronic dislocation of the hip. He points out that it is *not* an operation primarily suitable for the subluxated hip but for the congenitally dislocated hip. He shows the results in twenty-six hips, fifteen of which were excellent, six good, three fair and two stiff. The tables describing in detail the methods of treatment at each stage are a good feature of this paper. Platt discusses the late results of closed reduction in congenital dislocation of the hip. In a table he shows the late functional and anatomical results in eighty-six patients (110 hip joints) treated by manipulative reduction. Very satisfactory functional results occurred in ninety-three out of the 110 hips (84 per cent), but the anatomical results were very good in only fifty-seven hips (52 per cent). One most important cause of the poor anatomical results is the not infrequent appearance of osteochondritic changes in the femoral epiphysis after closed reduction. In recent years the trauma of manipulation has been generally accepted as a logical explanation of the vascular disturbance that causes the osteochondritis. Gradual reduction on an abduction frame is used by Scott of Oxford and has resulted in a reduction of the incidence from 25 per cent to 8 per cent.

Robert Ray of Seattle has an interesting article on tissue culture studies of bone growth and metabolism, and McLean, physiologist from Chicago, discusses the physiologic turnover of the mineral of bone. A most striking experimental observation was the rapid disappearance of intravenously injected Ca^{45} or P^{32} from the blood with its subsequent appearance in the skeleton. This rate of appearance in the bone is too rapid to be accounted for in terms of new formation of bone. In young animals an amount of calcium equivalent to that present in the blood may be turned over every minute; this is a figure beyond all possibility of expectation from information available before the introduction of tracer methods.

This volume is a very happy memorial of a considerable event in New York Orthopaedic circles.—Walter MERCER.

INTRA-OSSEOUS VENOGRAPHIES OF MEDIAL FRACTURES OF THE FEMORAL NECK. The residual vascularity of the head fragment in different types of fractures and its relation to the prognosis. By Anders HULTH. $9\frac{1}{2} \times 7$ in. Pp. 112, with 50 figures and 7 tables. 1956. Stockholm: Acta Chirurgica Scandinavica, Supplementum 214. Price Sw. cr. 20.

The high proportion of femoral heads that become necrotic after fractures of the neck has prompted the study of several methods to determine the viability of the femoral head soon after the injury. Isotopic activity of the head, arteriography and venography are among the procedures now under study and this monograph is another important contribution towards the final solution of this pressing problem, if we consider that more than one-third of all the femoral heads die as a consequence of a fracture of the neck.

The author takes advantage of the ability of the interosseous veins to take over any non-irritant fluid perfused into the bone. He uses 2 millilitres of a 50 per cent solution of Umbril, an iodine contrast medium. A special cannula is introduced through the trochanter up to the femoral neck like the guide of a Sven Johanssen nail. Two antero-posterior radiographs are obtained, one at the end of the perfusion and another two minutes later. The assessment of the condition of the femoral head is based on the speed with which the contrast medium has been removed, at the time the second radiograph is taken.

In general, a *positive* venograph would indicate a healthy head while a *negative* film suggests that the head is dead. Unfortunately, the method does not always give definite information for two reasons. Firstly, only 62 per cent of the perfused heads give a clear positive result, the rest being either negative or doubtful. Secondly, a good positive venograph does not exclude the possibility of a necrotic head, for a permeable arterial system to the femoral head at the time of perfusion does not eliminate the occurrence of the death of the osteocytes during a previous and transient occlusion of the vessels. About half of the necrotic heads were detected by this method, for one-third of the positive and apparently normal venographs corresponded to heads which suffered from aseptic necrosis within the first year of observation.

This is an excellent report on one of the more serious and meticulous works on the subject and the author is to be congratulated for the amount and objectivity of the information it provides on a problem which is in urgent need of a solution.—J. TRUETA.

HANDBOOK ON POLIOMYELITIS. By Joseph TRUETA, M.D., D.Sc.(Hon.) (Oxon.), F.R.C.S. (Hon.) (Canada), F.R.C.S., Nuffield Professor of Orthopaedic Surgery, University of Oxford; A. B. Kinnier WILSON, M.A., M.B., M.R.C.P., D.P.M., Member of the Scientific Staff, Medical Research Council, at the Institute of Orthopaedics, London, and at The Poliomyelitis Centre, Hendon Infectious Diseases Hospital, and The Royal National Orthopaedic Hospital, Stanmore, Middlesex; and Margaret AGERHOLM, M.A., B.M., B.Ch. (Oxon.), Assistant, Nuffield Department of Orthopaedic Surgery, Nuffield Orthopaedic Centre, Oxford. 9×6 in. Pp. vi+139, with 34 figures. Index. 1956. Oxford: Blackwell Scientific Publications. Price 20s.

It would be difficult to find three writers whose combined personal experience was better able to encompass the many aspects of acute anterior poliomyelitis and its sequelae. It is unfortunate, then, that the strict editing that must have been made to allow all the relevant subjects from virology to social resettlement to be included in so few pages should have excluded so much more that might have been gleaned from their comprehensive knowledge of the subject.

The fly-leaf of the book states that " it is written with particular reference to the needs of the general practitioner and the doctor in the infectious diseases hospital." To this might be added that it will satisfy the needs of the orthopaedic surgeon who wishes to keep in touch with what the general practitioner and the doctor in the infectious diseases hospital should know. In the sections of the book that are concerned with the epidemiology, virology and pathogenesis of poliomyelitis the facts are succinctly, if a trifle dogmatically, presented, and recent additions to knowledge in these fields are well represented. The account of the pathology is less well balanced. As much space is devoted to the equivocal changes in the sympathetic nervous system as to the changes in the motor nerve cells that are the basic feature of the disease. A note on the sequence of the cell changes illustrated in Figure 3 would be useful and a reference to Bodian's work would be appropriate. In the same chapter we are asked to accept that the denervation changes in muscle are the basis of the development of contractures and hypermobility in the early weeks of the disease, an explanation that seems altogether too facile to explain the peculiarly constant distribution of these contractures largely irrespective of the exact degree of paralysis in the affected muscles.

The chapter on diagnosis and differential diagnosis is straightforward and precise. The authors' view that " lumbar puncture has often been thought to precipitate and increase paralysis . . . until this view has been disproved lumbar puncture must be regarded as contra-indicated in poliomyelitis, to be used only when there is real doubt . . ." is worth serious consideration. Whether the administration of gamma globulin to particularly susceptible contacts, as advocated in the succeeding chapter on specific treatment and prevention, is of substantial value, assuming that it can be achieved, is open to debate.

The management of the acute stage is briefly but adequately covered. The importance of correct positioning of affected limbs is emphasised; the figures that illustrate this depict a young child, but would the splintage be adequate in an infant? Hot pack treatment is given its proper place in the relief of pain and " spasm."

Chapters 8 and 9 on respiratory complications are two of the best chapters, possibly because they have been allotted sufficient space to be informative without being discursive. Types of respirator and their application are shown, and the management and difficulties of management of the various combinations of paralysis of respiration and swallowing are well described. The later chapter on weaning from respiratory aid is also well set out and gives some very useful hints. A note on the late complications of prolonged respirator treatment, such as renal calculus, might have made this aspect of poliomyelitis complete. Unfortunately, the figures have suffered in several ways. Figure 11 is barely recognisable as a radiograph and the labelling suggests that the trachea is a double-barrelled structure. Figure 15 has no reference to it in the text, and the references to Figures 18 on p. 66, 19 on p. 67, and 10 on p. 72 do not correspond with the illustrations.

The conception of a " transitional stage " between the acute stage and the recovery period, lasting between one and eight weeks from the third week of the acute stage and characterised by absence of further spread of paralysis but persistence of irritability of the central nervous system, is useful in indicating the need for caution in the use of strenuous exercises until it is safe.

The principles that underlie the mechanism of muscle recovery are simply and clearly stated. They are followed by a description of the method of muscle training that has become the accepted one in most centres in this country—restoration of passive movements, carefully graduated exercises encouraging weaker muscles but not fatiguing them, pool therapy and, in due course, heavier resistance exercises and restoration of functional action in the limbs. Stress is rightly laid on the detection and elimination of contractures, but there seems to be some confusion between contractures that have persisted from the acute stage and deformities that may develop later as the result of muscle pull and limb growth. The text is easily read and conversational in tone, but cannot words like " posturisation " be avoided?

The final chapter on the management of the permanent disability is disappointing. It could hardly be otherwise to an orthopaedic reader when such important and difficult subjects as the use of apparatus, the place of corrective and reconstructive surgery, and rehabilitation and social resettlement are condensed together into a total of twelve small pages. As the writer says, " such a discourse is obviously beyond the scope of a book of this nature," but it is a pity that this, the first book on poliomyelitis to come from British orthopaedic centres, should give so little guidance in this field.—W. J. SHARRARD.

POLIOMYELITIS. By W. Ritchie RUSSELL, *C.B.E.*, M.D., D.Sc., F.R.C.P., Director, Department of Neurology, United Oxford Hospitals; Clinical Lecturer in Neurology, University of Oxford; Consultant Neurologist to the Army. Second edition. $9 \times 5\frac{1}{2}$ in. Pp. xi. + 147, with 40 figures. Index. 1956. London: Edward Arnold (Publishers) Ltd. Price 16s.

The second edition of this book is longer by nearly sixty pages and the revision has been extremely thorough. The sections on the acute diseases are, if possible, better than ever and the expanded chapters on bulbar and respiratory paralysis will be particularly welcome to those who have to deal with these grave conditions. Dr Ritchie Russell has set out his views, which he holds very strongly, on the management of poliomyelitis in its early stages. He is against the routine admission of patients to infectious diseases hospitals, and he believes there is much to be said in favour of caring for patients with bulbar or respiratory paralysis in a special unit within the curtilage of a general hospital where the necessary expert aid, particularly that of the anaesthetist, is available day and night. He is persuaded that the risk that the disease may spread to others is negligible. Ritchie Russell is still not at ease in dealing with somatic paralysis. For example, in discussing paralysis of the trunk muscles he says " it is clear therefore that this group . . . requires prolonged periods of care in the lying position much of which should be spent in the prone posture," suggesting that in this way the development of spinal deformity may be retarded. This once prevalent idea has been exploded; the chief cause of spinal deformity is asymmetrical paralysis for which, as yet, no real remedy exists.

This good book is marred by a few inaccuracies that one does not expect from so felicitous a writer, such as precipitous instead of precipitate, construction instead of constriction and subluxation of the odontoid process for what most people call atlanto-axial subluxation. But these are only minor blemishes.—H. J. SEDDON.

THE MANAGEMENT OF FRACTURES, DISLOCATIONS AND SPRAINS. By John Albert KEY, B.S., M.D., F.A.C.S., Clinical Professor Emeritus of Orthopaedic Surgery, Washington University School of Medicine, Associate Surgeon, Barnes, Children's and City Hospitals, St Louis, Missouri; and H. Earle CONWELL, M.D., F.A.C.S., Associate Professor of Orthopaedic Surgery, University of Alabama School of Medicine, Associate Orthopaedic Surgeon, University Hospital, Birmingham, Alabama. Sixth edition. 10×7 in. Pp. 1,168, with 1,123 figures. Index. 1956. London: Henry Kimpton. Price £7, 10s.

The sixth edition is slightly reduced in size compared with its predecessor. When I reviewed this in 1951 I commented on the need for removing some of the many photographs, a number of which did not elucidate the text. Some of these have disappeared but the criticism may still be made. The text otherwise has been brought into line with recent developments, and the chapter on fractures of the hand has been improved. The chapter on intramedullary nailing is well balanced and cautious in its enthusiasm for this method, valuable in a limited application. The book presents a very well planned and judicious survey of the American approach to fracture problems, and the authors are to be congratulated on yet another edition of this famous text-book which, as they note in their preface, may be regarded as their silver anniversary edition.—J. I. P. JAMES.

DORSAL ACETABULAR FRACTURES OF THE HIP (DASHBOARD FRACTURES). By Åke WALLER. 9½×7 in. Pp. 94, with 48 figures and 20 tables. 1955. Stockholm: Acta Chirurgica Scandinavica, Supplementum 205. Price Sw. cr. 15.

This excellent monograph deals with fracture of the posterior acetabular rim, particularly when associated with dorsal dislocation of the hip. It is concise, well written, authoritative, and likely to remain a standard work on this subject. After an adequate outline of the previous literature, the author gives an account of his ultimately successful efforts to reproduce these injuries in the corpse, and of the forces necessary to do so. He analyses 106 clinical cases, all but twenty-four associated with dislocations.

One of the many useful points in this work is the demonstration of the technique and of the value of a posterior oblique projection in the radiological investigation of this injury. Operative replacement of the displaced fragment is regarded as the best method of treatment, and this view is supported by an adequate follow-up.

This monograph will be found valuable by any surgeon who is called upon to treat the injuries inflicted by modern road transport.—D. Ll. GRIFFITHS.

A COMPANION IN SURGICAL STUDIES. Ian AIRD, Ch.M., F.R.C.S., Professor of Surgery in the University of London; Director of the Surgical Unit, Postgraduate Medical School of London, Hammersmith Hospital. Second edition. 10×7¾ in. Pp. xii+1,302, with 2 figures. Index. 1957. Edinburgh and London: E. & S. Livingstone Ltd. Price £4. 4s.

In spite of an imposing list of subjects mentioned in the introduction this edition is much the same as the first, which was published eight years ago. Like everything else it bears the imprint of inflation. Two hundred and forty-two pages have been added and it costs a guinea more. The increase in price is inevitable. So too is an increase in knowledge. Aird has not neglected the latter but he is miserly in his dislike of rejecting old wives' tales. Much of what our forefathers wrote we now know to be rubbish, and few papers over ten years old are worth reading. This book would improve in appearance if it lost a little weight. Two illustrations have crept in, which I think is a pity; for, unadorned, the *Companion* would still remain a masterpiece.—George PERKINS.

REHABILITATION LITERATURE, 1950–1955. A bibliographic review of the medical care, education, employment, welfare, and psychology of handicapped children and adults. Compiled by Earl C. GRAHAM, Librarian, and Marjorie M. MULLEN, Assistant Librarian, National Society for Crippled Children and Adults. 10×7½ in. Pp. xi+621. 1956. New York, Toronto, London: The Blakiston Division, McGraw-Hill Book Company Inc. Price $13.00.

The growing emphasis on rehabilitation as a fundamental part of treatment has brought with it an ever increasing volume of literature. Ranging as this subject does over so many disciplines, both medical and non-medical, its literature tends to be somewhat scattered, and for this reason a key should be especially welcomed. This book is an annotated bibliography of over 5,000 publications in the English language covering all phases of rehabilitation and all types of disorders. Items are numbered consecutively and set out clearly under alphabetically arranged subject headings. An author index has been added. Workers in rehabilitation should find it easy to turn up the literature within their own special sphere of interest, and, moreover, gain an idea of what is being done in related fields. This bibliography is supplemented by the monthly issues of "Rehabilitation Literature." These, we may hope, will in due course form the basis of further cumulated volumes—either in the form of new editions of the one under review, or as supplementary volumes.—C. DAVENPORT.

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